The student's guide to structural, morphological and ...

Robert Bentley

C

16595 f. 1

THE STUDENT'S GUIDE

TO

STRUCTURAL AND PHYSIOLOGICAL

BOTANY

THE STUDENT'S GUIDE

TO

STRUCTURAL, MORPHOLOGICAL, AND PHYSIOLOGICAL

BOTANY

BY

ROBERT BENTLEY, F.L.S., M.R.C.S.Eng.

FELLOW OF KING'S COLLEGE, LONDON
HONORARY MEMBER OF THE PHARMACEUTICAL SOCIETY OF GREAT BRITAIN
HONORARY MEMBER OF THE AMERICAN PHARMACEUTICAL ASSOCIATION
PROFESSOR OF BOTANY IN KING'S COLLEGE, LONDON
PROFESSOR OF BOTANY AND MATERIA MEDICA TO THE PHARMACEUTICAL
SOCIETY OF GREAT BRITAIN

LONDON
J. & A. CHURCHILL
11 NEW BURLINGTON STREET
1883

16595.

BODLEIAN LIBRARY
27 AUG 83
OXFORD.

PREFACE.

THE present volume has been prepared in accordance with a desire expressed for some years past, by many old pupils and others, to have a guide which should not be too elementary, but which might serve as an introduction to the author's 'Manual of Botany,' and other larger and more comprehensive works. The author has, therefore, endeavoured to condense within a moderate compass all that is essential as a foundation for future study, and thus to form a convenient and trustworthy guide on Structural and Physiological Botany for Medical and Pharmaceutical Students, and also for use in colleges and schools where Botany is now largely taught.

The author's experience for more than thirty years as a Professor of Botany has shown him the necessity of explaining every detail in simple language, and of arranging the subjects treated of in such a manner as to facilitate their systematic study. He has, therefore, taken his own successful 'Manual of Botany' as his guide in these respects, but has altered it wherever necessary, so as to adapt the present work to a less advanced class of students. A comparison of the present volume, however, with his larger work will show that, although it has been grounded upon it, it cannot be regarded as a simple abstract or epitome of that volume, but that every page exhibits evidence of very careful revision, and much that is new in the treatment of details. Indeed, great pains have been taken to bring the different subjects treated of down to the present state of science; and much care has also been exercised in condensing the numerous details in each department, and in arranging them for systematic study. The author trusts, therefore, that he has succeeded in the object he had in view, and has satisfied those who expressed a desire for such a volume.

The present work will be succeeded, as early as possible, by another small volume, 'The Student's Guide to Systematic Botany,' uniform with it in design and execution.

June 1883.

CONTENTS.

PAGE
GENERAL INTRODUCTION 1

BOOK I.

ORGANOGRAPHY; OR, STRUCTURAL AND MORPHOLOGICAL BOTANY.

CHAPTER I.

GENERAL MORPHOLOGY OF THE PLANT . . 6

1. Organs of Nutrition 15
2. Organs of Reproduction 17

CHAPTER II.

ELEMENTARY STRUCTURE OF PLANTS, OR VEGETABLE HISTOLOGY 23

SECTION 1.

OF THE CELL AS AN INDIVIDUAL . . . 23

1. Nature of the Cell and its Contents 24
2. Forms and Sizes of Cells 37
3. General Properties and Structure of the Cell-wall . 41

SECTION 2.

OF THE KINDS OF CELLS AND THEIR CONNEXION WITH ONE ANOTHER 45

1. Parenchyma 45
2. Prosenchyma 48

PAGE
3. Vessels 49
4. Epidermal Tissue 55
5. Appendages of the Epidermis 59
6. Intercellular System 66

CHAPTER III.

ORGANS OF NUTRITION . . . 68

SECTION 1.

THE STEM OR CAULOME 68

1. Internal Structure of the Stem in general 69
  A. Exogenous or Dicotyledonous Stem 75
  B. Endogenous or Monocotyledonous Stem 88
  C. Acrogenous or Acotyledonous Stem 95
2. Buds and Ramification 98
  A. Leaf-buds or Buds 98
  B. Ramification or Branching 103
3. Of the Forms and Kinds of Stems and Branches . . 107
  A. Forms of Stems 107
  B. Kinds of Stems 109

SECTION 2.

THE ROOT OR DESCENDING AXIS . . 116

1. True or Primary Root 117
2. Adventitious or Secondary Root 119
Roots of Dicotyledonous, Monocotyledonous, and Acotyledonous Plants 124
Forms of Roots 126

SECTION 3.

THE LEAF OR PHYLLOME 129

1. General Description and Parts of the Leaf 129
2. Internal Structure of Leaves 131
  (1) Aerial Leaves 131
  (2) Submersed Leaves 135
3. Insertion and Arrangement of Leaves 136
  (1) Insertion 136
  (2) Arrangement 137
  (3) Arrangement of the Leaves in the Bud, or Vernation 139

PAGE
4. Lamina or Blade 142
Venation 143
Composition 148
(1) Simple Leaves 149
(2) Compound Leaves 161
5. Petiole or Leaf-stalk 165
6. Stipules 168
7. Anomalous Forms of Leaves 171
8. General View of the Leaves in the Three Classes of Plants 174

CHAPTER IV.

ORGANS OF REPRODUCTION IN THE PHANEROGAMIA . 176

SECTION 1.

INFLORESCENCE OR ANTHOTAXIS . . . 176

1. The Bract 176
2. The Peduncle or Flower-stalk 182
3. Kinds of Inflorescence 186
(1) Indefinite, Indeterminate, or Axillary Inflorescence 187
(2) Definite, Determinate, or Terminal Inflorescence . 195
(3) Mixed Inflorescence 203

SECTION 2.

OF THE PARTS OF THE FLOWER, AND THEIR ARRANGEMENT IN THE FLOWER-BUD 204

1. Parts of the Flower 204
2. Æstivation or Præfloration 204

SECTION 3.

THE FLORAL ENVELOPES 208

1. The Calyx 208
(1) Polysepalous or Dialysepalous Calyx . . . 210
(2) Monosepalous or Gamosepalous Calyx . . . 211
Appendages of the Calyx 214
Duration of the Calyx 215

PAGE
2. The Corolla 216
(1) Polypetalous or Dialypetalous Corolla 218
(2) Monopetalous or Gamopetalous Corolla 220
Appendages of the Corolla 223
Duration of the Corolla 225

SECTION 4.

ESSENTIAL ORGANS OF REPRODUCTION . . 226

1. The Andrœcium 227
(1) The Filament 227
(2) The Anther 230
The Stamens generally, or the Andrœcium . . 238
The Pollen 243
2. The Disk 248
3. The Gynœcium or Pistil 250
The Carpel 250
The Gynœcium 255
(1) The Ovary 260
(2) The Style 266
(3) The Stigma 268
4. The Thalamus 271

SECTION 5.

THE FRUIT 273

Nature and General Characters of the Fruit 273
Composition of the Fruit 275
Dehiscence of the Fruit 277
1. Valvular Dehiscence 279
2. Transverse or Circumscissile Dehiscence . . . 285
3. Porous Dehiscence 286
Kinds of Fruits 287
1. Fruits formed by a Single Flower 288
2. Fruits formed by the Combination of Several Flowers 300

SECTION 6.

THE OVULE AND SEED 302

1. The Ovule 302
Development and Structure 305
Relation of the Hilum, Chalaza, and Micropyle to one another 308

PAGE
2. The Seed 310
Nature and General Characters 310
Forms of Seeds 311
Structure of the Seed 312
(1) The Integuments or Coats 312
(2) The Nucleus or Kernel 316

Section 7.

THEORETICAL STRUCTURE, OR GENERAL MORPHOLOGY OF THE FLOWER 326

CHAPTER V.

Reproductive Organs of Cryptogamous, Flowerless, or Acotyledonous Plants . . . 332

Section 1.

REPRODUCTIVE ORGANS OF CORMOPHYTES . . 333

1. Filices or Ferns 333
2. Equisetaceæ or Horsetails 337
3. Marsileaceæ or Pepperworts 338
4. Lycopodiaceæ or Club-mosses 341
5. Musci or Mosses 342
6. Hepaticaceæ or Liverworts 346

Section 2.

REPRODUCTIVE ORGANS OF THALLOPHYTES . . 350

1. Fungi or Mushrooms 350
2. Lichenes or Lichens 361
3. Characeæ or Charas 365
4. Algæ or Seaweeds 368

BOOK II.

PHYSIOLOGY OF PLANTS; OR, PHYSIOLOGICAL BOTANY.

CHAPTER I.

PAGE
SPECIAL PHYSIOLOGY OF THE ELEMENTARY STRUCTURES, AND OF THE ORGANS OF NUTRITION . . 376

SECTION 1.

PHYSIOLOGY OF THE ELEMENTARY STRUCTURES . 376

1. Functions of Parenchymatous Cells 376
    (1) Formation of Cells 377
        A. Free Cell-formation 377
        B. Cell-division 379
    (2) Absorption and Transmission of Fluids . . 382
    (3) Movements of the Cell-contents 384
    (4) Elaboration of the Cell-contents 386
2. Functions of Prosenchymatous Cells 387
3. Functions of Vessels 387
4. Functions of Epidermal Tissue 388
5. Functions of the Appendages of the Epidermis . . 389
6. Functions of the Intercellular System 390

SECTION 2.

PHYSIOLOGY OF THE ORGANS OF NUTRITION . 390

1. Of the Root or Descending Axis 390
2. Of the Stem or Caulome 394
3. Of the Leaves 397

CHAPTER II.

GENERAL PHYSIOLOGY, OR LIFE OF THE WHOLE PLANT . 409

SECTION 1.

FOOD OF PLANTS, AND ITS SOURCES . . 410

1. Organic Constituents 411
2. Inorganic Constituents 413

SECTION 2.

PAGE
LIFE OF THE WHOLE PLANT, OR THE PLANT IN ACTION . 415

1. Absorption 415
2. Distribution of Fluid Matters through the Plant, and their Alteration in the Leaves 416

CHAPTER III.

PHYSIOLOGY OF THE ORGANS OF REPRODUCTION . 424

1. Functions of Bracts and Floral Envelopes . . . 424
2. Functions of the Essential Organs of Reproduction . 426
    (1) Reproduction of Cryptogamous or Acotyledonous Plants 427
        A. Reproduction of Thallophytes 427
        B. Reproduction of Cormophytes . . . 428
            i. Hepaticaceæ 428
            ii. Musci 429
            iii. Lycopodiaceæ 430
            iv. Marsileaceæ 431
            v. Equisetaceæ 432
            vi. Filices 432
    (2) Reproduction of Phanerogamous or Cotyledonous Plants 433
        A. Reproduction of Gymnospermia 434
        B. Reproduction of Angiospermia 437
    Hybridisation 442
3. Of the Fruit 444
    Chemical Constitution of Fruits 444
    Ripening of Fruits 446
4. Of the Seed 446
    Germination 447

CHAPTER IV.

SPECIAL PHENOMENA IN THE LIFE OF THE PLANT. 452

1. Development of Heat by Plants 452
2. Luminosity of Plants 453
3. Electricity of Plants 454
4. Movements of Plants 455
5. Odours of Plants 463

INDEX. 465

Corrections and Additions.

Page 23, line 6 from top, *for* fig. 11 *read* fig. 12.
„ 27, „ 9 „ bottom, *for* k′ k′ *read* k k.
„ 32, „ 7 „ „ *for* has proved *read* has also proved.
„ 35, „ 14 „ top, *erase* comma *after* Cystoliths.
„ 51, „ 7 „ „ *for* divisions *read* division.
„ 55, „ 9 „ „ *erase* comma *after* Fibro-vascular.
„ 90, „ 15 „ „ *for* fig. 130 *read* fig. 129.
„ 124, „ 12 „ „ *for* mood *read* mode.
„ 126, „ 6 „ bottom, *for* fig. 170 *read* fig. 169.
„ 138, „ 8 „ top, *after* stem *insert* at the same level.
„ 266, „ 6 „ bottom, *for* page 271 *read* page 274.
„ 300, „ 7 „ „ *for* page 271 *read* page 274.
„ 326, „ 11 „ „ *for* page 305 *read* page 304.
„ 332, „ 11 „ „ *erase* comma *after* Pistillidia.
„ 334, „ 2 „ „ *for* cases *read* case.
„ 350, „ 16 „ top, *for* fig. 503 *read* fig. 593.
„ 350, „ 20 „ „ *for* page 347 *read* page 346.
„ 372, „ 15 „ bottom, *after* organ *insert* (fig. 621, D, *w*).
„ 384, „ 10 „ „ *for* page 389 *read* page 388.
„ 388, „ 14 „ „ *for* page 309 *read* page 399.
„ 402, „ 6 „ *for* page 420 *read* page 421.
„ 403, „ 13 „ top, *for* page 420 *read* page 421.

THE STUDENT'S GUIDE
TO
STRUCTURAL, MORPHOLOGICAL, AND PHYSIOLOGICAL BOTANY.

GENERAL INTRODUCTION.

THE various bodies which are situated on the surface of the earth, or combined so as to form its substance, are naturally arranged in three great divisions, called, respectively, the *Animal*, *Vegetable*, and *Mineral Kingdoms*; and as those comprised in the two former are possessed of life, they are also termed Organic; while those of the latter, not being endowed with life, are called Inorganic. Botany is the science which treats of the lower members of the organic world, called Plants or Vegetables.

DEPARTMENTS OF BOTANY.—Botany in its extended sense embraces everything which has reference to plants either in a living or fossil state. It investigates their nature; their internal structure; their outward forms; the laws by which they are enabled to grow and propagate themselves; and their relations to one another, and to the other bodies by which they are surrounded. As a science, therefore, it is of great extent, and one which consequently requires for its successful prosecution the most careful and systematic study. It may be

1 2

divided into the following departments:—1. *Organography*: this comprises everything which relates to the internal structure and outward forms of plants, and their various parts or organs: that portion which treats of their structure, including the description of elementary structure or *Vegetable Histology*, is commonly termed *Structural Botany*; and that which has reference to their outward forms is called *Morphological Botany*, or the *Comparative Anatomy* of plants. 2. *Physiological Botany*: this treats of plants, and their organs, in a state of life or action. 3. *Systematic Botany*: this considers plants in their relations to one another, and comprehends their arrangement and classification. 4. *Geographical Botany* is that department which explains the laws which regulate the distribution of plants over the surface of the earth at the present time. And 5. *Fossil Botany* is that which investigates the nature and distribution of the plants which are found in a fossil state in the different strata of which the earth is composed. In this work our attention will be limited to a brief description of the first two departments, leaving Systematic Botany to be treated of in another volume.

DISTINCTIONS BETWEEN ANIMALS, PLANTS, AND MINERALS.—Botany being the science which treats of plants, it would naturally be expected that we should commence the subject by defining a plant. No such definition can, however, be given in the present state of our knowledge of the organic world, neither is it probable that, as our knowledge increases, such will ever be the case; for hitherto the progress of inquiry has shown that there is no distinct line of demarcation between plants and animals, the one passing gradually and imperceptibly into the other. Indeed, until quite recently it was believed by many, that there existed certain organisms which were plants at one period of their lives and animals at another. There are even some naturalists who believe that there is no line of demarcation between plants and minerals, but that simple organisms can be, and are, formed out of inorganic matter; but we hold such notions to be purely speculative, and maintain that the possession of individual life and power of reproduction in the former, constitute a broad and well-marked line of demarcation from the latter. Even when we compare plants with animals, so long as we confine our researches to the higher members of the two kingdoms, the distinctions are evident enough; it is only when we look more deeply into the subject, and compare together those bodies which are placed lowest in the scale of creation, that we find the impossibility of laying down any certain characteristics by which all the members of the two kingdoms may be absolutely distinguished. We shall at present, therefore, confine our attention to those characters which, as a general rule, are applicable, but to which exceptions may be found when we compare particular individuals.

In the first place, we find that plants derive their nourishment from the earth and the air or water by which they are surrounded, and that they alone have the power of converting this inorganic matter into organic. Animals, on the contrary, live on organic matter, and reconvert it into inorganic. In other words, plants produce organic matter, and animals consume it.

Secondly, plants are generally fixed to the soil, or to the substance upon which they grow, and derive their food immediately by absorption through their external surface; while animals, being possessed of sensation and power of voluntary motion, can wander about in search of the food that has been prepared for them by plants and by other animals, and which they receive into an internal cavity or stomach. Plants are, therefore, to be regarded as destitute of sensation and power of voluntary motion, and as being nourished from without; while animals are possessed of such attributes, and are nourished from within.

Thirdly, the action of plants and animals on the atmosphere is different. Thus, during the process of what has been called assimilation, plants decompose the carbon-dioxide of the air or water in which they are growing, fix the carbon, which is obtained from this decomposition, and restore the oxygen. Animals, on the contrary, during the process of respiration take into their tissues free oxygen, and return, in its place, to the surrounding medium in which they live, carbon-dioxide, the result of the combination of the superfluous carbon in the animal system with the oxygen which has been inhaled.

Fourthly, while all plants and animals are made up of cells, those of the latter do not develop upon their exterior any substance essentially differing from the more internal protoplasm; but the whole substance of the cell is more or less homogeneous, and consists throughout of matter which is composed of the four elements, Carbon, Oxygen, Hydrogen, and Nitrogen. The protoplasmic mass forming the cells of plants, which is also composed of the same four elements, on the other hand, sooner or later becomes changed on its outer surface; a membranous covering is developed which is termed the *cell-wall*, and the substance of which it is composed is called *cellulose*, which is destitute of nitrogen, but consists entirely of the three elements, Carbon, Oxygen, and Hydrogen.

The presence of starch was also formerly considered as a diagnostic character of plants; but it is now known that this substance, or at least one isomeric with, and presenting the same general appearances as, it, is also to be found in the tissues of animals.

We arrive accordingly at the conclusion that it is impossible to define a plant, or, in other words, to lay down any single character by which plants can in all cases be distinguished from animals. In determining, then, whether an organism under investigation be a plant or an animal, the naturalist must first take into his consideration, not any one character alone, but the sum of all the characters which it may exhibit.

BOOK I.

ORGANOGRAPHY; OR, STRUCTURAL AND MORPHOLOGICAL BOTANY.

THE most superficial examination by the unassisted eye of any of the higher plants enables us to distinguish various parts or organs, as root, stem, leaves, and the parts of the flower. A similar examination of plants of lower organisation presents to our notice either the same organs as, or organs of an analogous nature to, those of the higher plants. By a more minute examination of these several organs by the microscope, it will be found that they are all made up of others of a simpler kind, in the form of little membranous closed sacs, called cells, and elongated tubular bodies, of various forms, sizes, and appearances, which are combined together in various ways. Hence, in describing a plant, we have two sets of organs to allude to, namely, the compound organs or those which are visible to the naked eye, and the elementary structures of which they are composed. A knowledge of these elementary structures is absolutely essential to a complete and satisfactory acquaintance with the compound organs; but, previously to describing them, it will materially assist our investigations if we give a general sketch of the compound organs, and of the plants which are formed by their union. According to the number of these compound organs, and the greater or less complexity which they exhibit, so, in a corresponding degree, do plants vary in such particulars. Hence we find plants exhibiting a great variety of forms; that part of Botany which has for its object the study of these forms of plants and of their several parts or organs is called Morphology; while that part which relates to their internal structure, including the description of elementary structure or Vegetable Histology, is commonly termed Structural Botany. These two parts together constitute that department of Botany which is usually termed Organography. These parts are most conveniently studied together; we shall therefore, after a description of the General Morphology of the Plant, and of the Elementary Structures which are common to all parts of plants, proceed to consider separately the different organs which are made up of these elementary structures both with reference to their external forms and internal structure.

CHAPTER I.

GENERAL MORPHOLOGY OF THE PLANT.

THE simplest plants, such as the Red Snow (*Protococcus*), (*fig.* 1), consist of a single membranous sac, or *cell* as it is termed, which in form is more or less spherical or oval. In plants immediately above these in point of complexity we find the cells still all alike, but instead of being separated, and each forming a distinct plant, they are joined end to end and form a many-celled filament which is straight or curved in various ways, as in *Oscillatoria* (*fig.* 2). All these plants—so far at least as is known—multiply by division of their cells only; but a little higher in the scale we meet with plants in which certain of their cells perform the func-

FIG. 1.

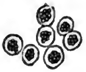


Fig. 1. Several Red Snow plants (*Protococcus* (*Palmella*) *nivalis*), magnified.

tion of nutrition, while others are set apart for the purpose of reproduction. Thus, in the Moulds, such as *Mucor* (*fig.* 3), or *Penicillium* (*fig.* 4), the cells which serve as organs of nutrition form branched, jointed filaments, or *hyphæ* (see page 47), which lie upon the surface of the substance furnishing the plants with food; while those destined to reproduce the individual, which are called *spores*, are developed in globular cavities

FIG. 2.

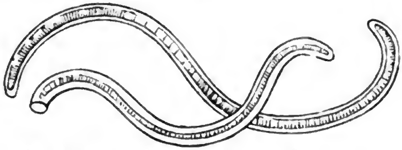


Fig. 2. Two plants of *Oscillatoria spiralis.*

FIG. 3.

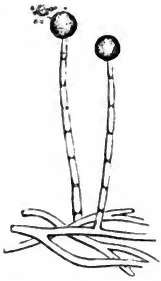


FIG. 4.

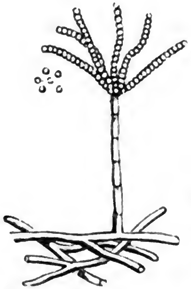


FIG. 5.

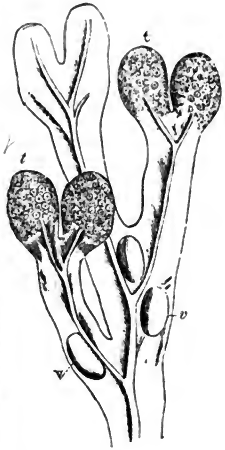


Fig. 3. A species of Mould (*Mucor*), with branched mycelium (*hyphal tissue*) below, from which two stalks are seen to arise, each of which is terminated by a sac (*sporangium* or *ascus*), from which a number of minute bodies (*spores*) are escaping.—*Fig.* 4. Another Mould (*Penicillium glaucum*), with branched mycelium (*hyphal tissue*), and stalk bearing several rows of cells, which are the germinating spores (*conidia*).—*Fig.* 5. Thallus or thallome of the common Bladder Sea-weed (*Fucus vesiculosus*). *t*, *t*. The fructification. *v*, *v*. Bladders of air.

(*sporangia*), as in *Mucor* (*fig.* 3), or are arranged in necklace-like branches at the end of special filaments, as in *Penicillium* (*fig.* 4).

Yet a little higher in the scale of vegetable life we find the cells so combined as to form leaf-like expansions (*fig.* 5), or solid axes, as well as special organs of reproduction (*fig.* 5, *t*, *t*). But these cells are all more or less alike, so that no true distinction can be drawn between the often very different looking parts we meet with in such plants as a sea-weed or a mushroom. Such a combination of similar cells, whatever the precise form may be, which presents no differentiation of leaf, stem, and root, is called a *thallus* or *thallome*, and every thallus-producing plant is therefore termed a *Thallophyte* or *Thallogen*. Under the head of Thallophytes we comprise all those simpler forms of plants which are commonly known as Algæ, Lichens, and Fungi.

FIG. 6.

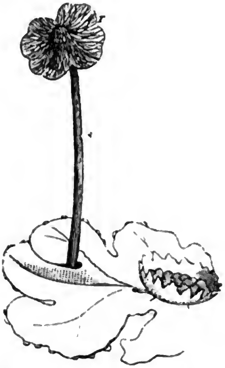


FIG. 7.

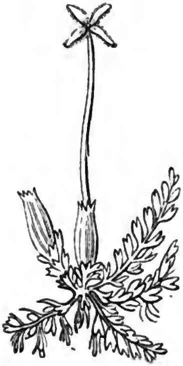


Fig. 6. A portion of the flat thalloid stem of *Marchantia polymorpha*, showing an antheridial receptacle, *r*, supported on a stalk, *s*.——*Fig.* 7. *Jungermannia bidentata*. The stem is creeping, and bears numerous small imbricated leaves.

Again, as all Thallophytes are composed of cells which approach more or less closely to the spherical or oval form, or if elongated are thin-walled and flexible, they are also termed *Cellular Plants*, in contradistinction to those which come above them which are called *Vascular Plants* on account of their commonly possessing, in addition to these cells which are termed parenchymatous, elongated thick-walled cells, called prosenchymatous or wood-cells (see page 39); and also, in most cases, except in the intermediate orders of Liverworts and Mosses, variously formed tubular organs which are known under the name of vessels.

From the Thallophytes, by various intermediate stages, through an order of plants called the Liverworts, we arrive at another order—the Mosses. In the lower forms of Liverworts, e.g. *Marchantia* (*fig.* 6), we have a green flat thallus-looking stem bearing upon its under surface scale-like appendages, the first representatives of true leaves. In the higher forms, as *Jungermannia* (*fig.* 7), the stem and leaves are both more highly developed. In the Mosses, e.g. *Polytrichum* (*fig.* 8), the stem often contains elongated cells, which are to a certain extent thickened, and differ little from the true wood-cells met with in higher plants; this tissue, too, is often prolonged into the leaf, when it forms a midrib. Correlated with this greater development of the organs of nutrition we find the reproductive apparatus similarly advanced in complexity of structure. The female element consists of a mass of protoplasm called the *germ* or *embryonic cell*, situated in the interior of a flask-shaped cellular organ, the *archegonium*, and this is fertilised by small spirally-wound filaments or *antherozoids*, which are developed in cells termed sperm-cells (*fig.* 9, *c*), formed inside a cellular sac-like structure called the *antheridium*, *a*. The result of this fertilisation is what is commonly termed the fructification (*fig.* 8), which will be hereafter described.

Still ascending, we find in the Club-mosses, Pepperworts, Horsetails (*fig.* 10), and Ferns (*fig.* 11), a con-

FIG. 8.

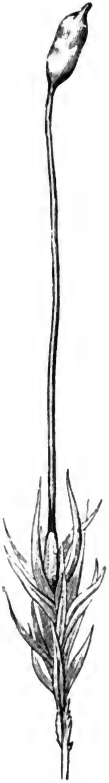


FIG. 9.

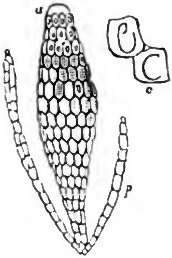


FIG. 11.

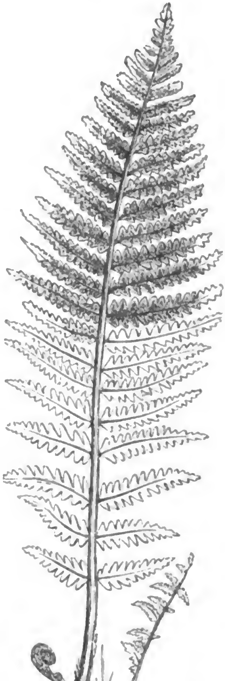


FIG. 10.

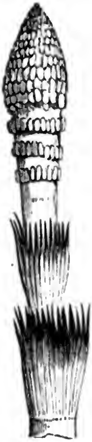


Fig. 8. Hair-moss (*Polytrichum*). with its leaves, stem, and fructification.——*Fig*. 9. Antheridium, *a*, of the Hair-Moss (*Polytrichum*), containing a number of cells, *c*, in each of which there is a single *antherozoid*. *p*. *Paraphyses*, surrounding the antheridium.——*Fig*. 10. Fructification of the Great Water Horsetail (*Equisetum maximum*), forming a cone-like mass at the end of the stem.——*Fig*. 11. The Male Fern (*Aspidium Filix-mas*).

tinued advancement in complexity of structure; *vessels* of different kinds make their appearance for the first time; and the stems of Ferns are frequently of considerable size and height. Thus, in the tropics and warmer parts of the earth, Ferns will sometimes attain the height of forty feet, bearing on their summit a large tuft of leaves, or, as they are commonly called, *fronds*; the latter term being applied to leaves which, like those of Ferns, bear their fructification or organs of reproduction. In these plants true roots first also appear, but they are generally broken up into numerous small fibres and never become enlarged as in the tap-roots (*fig.* 16, *r*) of the higher flowering plants.

In all the plants above mentioned we have no evident flowers as in the higher plants, hence they are called *Flowerless*; but their organs of reproduction are very small and inconspicuous, and therefore they are also termed *Cryptogamous*, that is to say, plants with concealed or invisible reproductive organs. These Cryptogamous plants are again divided into two groups, called *Cormophytes* and *Thallophytes*; the latter comprising the simpler forms of plants, which, as previously stated, are commonly known as Algæ, Fungi, and Lichens, and which present no distinction of root, stem, and leaf (*fig.* 5); and the former group those plants, such as the Liverworts (*fig.* 7), Mosses (*fig.* 8), Club-mosses, Pepperworts, Horsetails (*fig.* 10), and Ferns (*fig.* 11), which present us with a more or less evident stem, bearing leaves, and, except the Liverworts and Mosses, also true roots and vessels of different kinds.

All plants above those called Cryptogamous, from possessing evident flowers or reproductive organs, are termed *Phanerogamous*, *Phænogamous*, or *Flowering*. These latter plants are also reproduced by true *seeds* instead of *spores*, as is the case in all Cryptogamous plants which possess reproductive organs; a seed being essentially distinguished from a spore, from containing within itself in a rudimentary condition all the essential parts of the future plant in the form of an embryo (*fig.* 12); while a spore merely consists of a single cell, or of two or more united, and never exhibits any distinction of parts until it begins to develop in the ordinary process of vegetation, and then only in certain cases.

These Phanerogamous plants also present two well-marked divisions, called respectively the *Angiospermia* and the *Gymnospermia*: the former including those plants in which the ovules are enclosed in a case called an ovary (*fig.* 28, *o*, *o*); and the latter, such plants as the Fir, in which the ovules are naked (*fig.* 13, *ov*) or not enclosed in an ovary. In the Phanerogamous plants we have the highest and most perfect condition of vegetation; and it is to these that our attention will be more especially directed in the following pages. But before proceeding to describe in detail the elementary structures of these and other plants and the different parts or organs which they form by their combination, it will be more convenient and intelligible to give a general sketch of the nature and characters of these compound organs, and to explain the meaning of the various technical terms which are employed for their description.

FIG. 12.

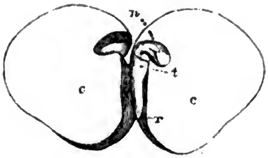


FIG. 13.

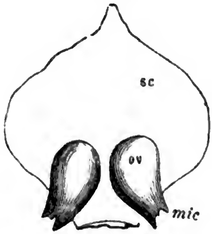


Fig. 12. Dicotyledonous embryo of the Pea. *r*. The radicle. *t* The axis (*tigellum*), terminated by the plumule, *n*. *c*, *c*. The cotyledons.——*Fig.* 13. Bract or carpellary leaf, *sc*, of a species of *Pinus*, bearing two naked ovules, *ov*, at its base. *mic*. The micropyle or foramen.

We have already stated that a seed contains an embryo, in which the essential parts or organs of the future plant are present in a rudimentary state. The embryo of a common Pea may be taken for the purpose of illustration (*fig.* 12). Here we find a distinct central axis, *t*, which is sometimes termed the *tigellum* or *tigelle*: the lower part of this is called the *radicle*, *r*; and its upper extremity, which is terminated by two or more rudimentary leaves, is known as the *plumule*, *n*. This axis is united to two fleshy lobes, *c*, *c*, to which the name of *cotyledons* has been given. But some seeds only contain one cotyledon in their embryo (*fig.* 15, *c*), instead of two as just described in the Pea; and hence we divide Phanerogamous plants, or those which are reproduced

FIG. 14.

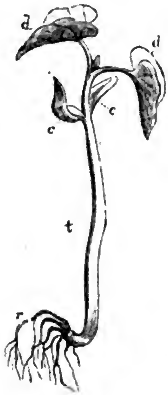


FIG. 15.

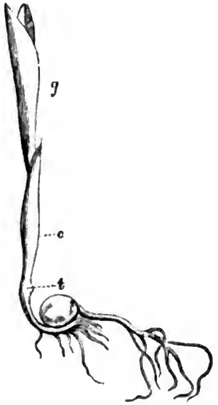


Fig. 14. Germination of the Haricot or French Bean, a Dicotyledonous plant. *r*. The roots, springing from the lower end of the axis, *t* (*tigellum*). *c*, *c*. The cotyledons. *d*, *d*. The leaves.—— *Fig.* 15. Germination of Maize, a Monocotyledonous plant. *t*. The axis, giving off roots from its lower extremity. *c*. The cotyledon. *g*. The leaves and young stalk.

by seeds, into two great classes, called, respectively, Dicotyledones and Monocotyledones. As Cryptogamous plants have no cotyledons, they are termed Acotyledonous; hence we have two great divisions of plants, the Cotyledones and the Acotyledones, the former being again divided into the Monocotyledones and the Dicotyledones.

When a seed is placed under favourable circumstances, its embryo begins to develop (*figs.* 14 and 15); the lower part of its axis, *t*, or radicle, or one or more branches from it, growing in a downward direction, while the upper part elongates upwards, carrying the plumule with it, and at the same time the cotyledonary portion becomes developed and forms the first leafy organs. This development of the embryo constitutes what is termed the process of germination. The office of the cotyledonary portion is only of a temporary nature, being simply designed to afford nutriment to the rudimentary parts of the future plant in the early stage of their growth; and we have thus produced a central axis developing in two opposite directions; the lower part of which is called the *descending axis* or *root* (*fig.* 14, *r*), and the upper the *ascending axis* or *stem*. Upon this ascending axis or its divisions all the future organs of the plant are arranged; those which immediately succeed the cotyledons, *c*, *c*, constitute the first true leaves of the plant, *d*, *d*; and all which succeed the leaves in the order of development, such as the flower and its parts, are merely modifications designed for special purposes of those organs which have preceded them. Hence these three essential organs—namely, root, stem, and leaves—are called *organs of nutrition* because they have for their object the nutrition of the plant to which they belong; while the flower and its parts have assigned to them the office of reproducing the plant by the formation of seeds, and are hence termed *organs of reproduction.*

In like manner, when a spore germinates, it either simply developes parts which, as we have seen, perform equally both nutritive and reproductive functions; or a certain special apparatus is designed for the latter purpose, as is the case in by far the larger number of Cryptogamous plants. We have here, therefore, as in Phanerogamous plants, two distinct series of organs, one adapted for nutrition, and another for reproduction. Hence in treating of the different organs of the plant, both in reference to their structure and life, we arrange them in two divisions: namely, 1. *Organs of Nutrition*; and 2. *Organs of Reproduction.* These organs we must now briefly describe, and explain the terms used to characterise their principal modifications.

FIG. 16.

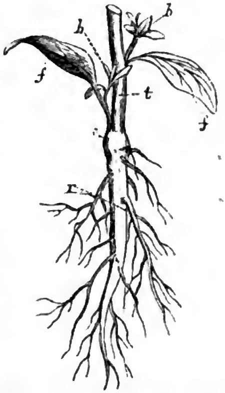


Fig. 16. Lower part of the stem and root of the common Stock. *r.* The root with its branches. *t.* The stem. *f, f.* Leaves. *b, b.* Buds in process of development.

1. ORGANS OF NUTRITION.

a. *The Root.*—The root (*fig.* 16, *r*) or descending axis is that part of a plant which at its first development in the embryo takes a direction opposite to the stem, avoiding the light and air, and fixing the plant to the soil or to the substance upon which it grows, or being suspended in the water when the plant is placed in that medium. The divisions of a root, which are given off irregularly and without any symmetrical arrangement, are termed branches.

b. *The Stem or Caulome.*—The stem (*fig.* 16, *t*) is that organ which at its first development passes upwards, and is hence termed the ascending axis, seeking the light and air, and bearing on its surface leaves, *f, f,* and other leafy appendages. The leaves are always developed at regular points upon the stem or branch, which are called *nodes*, and in the axil of every leaf (that is, in the angle produced by the junction of the base of the upper surface of the leaf with the stem) we find, under ordinary circumstances, a little conical body called a *leaf-bud* (*fig.* 18, *b*). From these leaf-buds the branches are subsequently produced, and hence, in the stem, these are symmetrically arranged, and not irregularly, as in the root, where there is no such special provision for their formation. It is in the presence of leaves and leaf-buds that we find the essential characteristics of a stem, as both these organs are absent in the root.

FIG. 17.

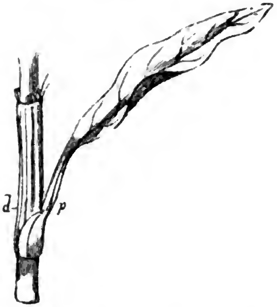


FIG. 18.

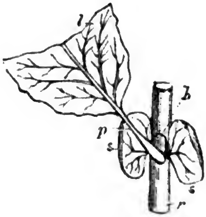


Fig. 17. Leaf and piece of stem of *Polygonum Hydropiper*. *l*. Lamina or blade. *p*. Petiole. *d*. Sheath or vagina.——*Fig.* 18. Leaf and portion of a branch of *Salix aurita*. *r*. Branch. *b*. Bud. *l*. Lamina with the upper portion removed, and attached by a petiole, *p*, to the stem. *s*, *s*. Caulinary stipules.

c. *The Leaf or Phyllome.*—The leaf is commonly a more or less flattened expansion of the stem or branch (*figs.* 17 and 18). In its highest state of development it consists of three parts; namely, of an expanded portion which is usually more or less flattened (*figs.* 17 and 18, *l*), called the *lamina* or *blade*; of a narrow portion by which this lamina is connected with the stem, termed the *petiole* or *leaf-stalk* (*figs.* 17 and 18, *p*); and of a third portion at its base which either exists in the form of a sheath (*fig.* 17, *d*) encircling the stem, or as two little leaf-like appendages on each side, which are called *stipules* (*fig.* 18, *s*, *s*). These three portions are by no means always present; for it frequently happens that one or two of them are absent; and in such cases when the petiole is wanting the leaf is said to be *sessile*, and if the stipules are absent the leaf is described as *exstipulate*.

FIG. 19.

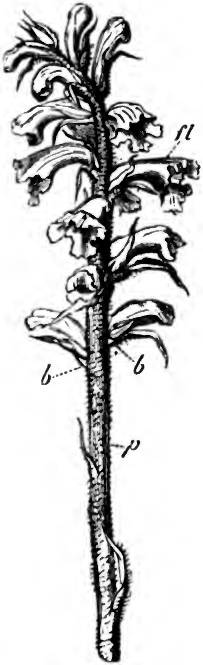


FIG. 20.

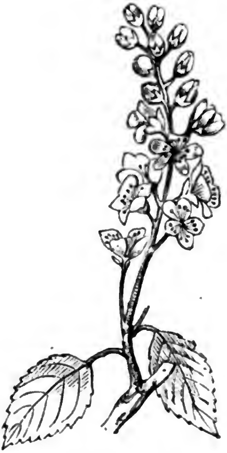


Fig. 19. Inflorescence of a species of Broom-rape (*Orobanche*). **p**. Peduncle. **b**, **b**. Bracts. **fl**. Flower. The flowers are sessile on the peduncle, and form the kind of inflorescence which is termed a *spike*.——*Fig.* 20. Inflorescence of a species of Cherry (*Prunus*). The flowers are arranged on pedicels, and form the kind of inflorescence called a *raceme*.

2. ORGANS OF REPRODUCTION.—a. *The Flower-stalk or Peduncle.*—The stalk which bears a solitary flower, as in the Tulip, or several sessile flowers (*fig.* 19, *p*),

is called the *flower-stalk* or *peduncle*; or if the stalk branches and each branch bears a flower, the main axis is still called a *peduncle*, and the stalk of each flower a *pedicel* (*fig.* 20); or if the axis be still further subdivided, the general name of peduncle is applied to the whole, with the exception of the stalks immediately supporting the flowers, which are in all cases called pedicels. The leaves which are placed upon the flower-stalk, and from the axils of which the flower-buds arise (*fig.* 19, *b*, *b*), are termed *bracts*. The flowers are variously arranged upon the peduncle, and to each mode of arrangement a special name is applied; the term *inflorescence* being used in a general sense to include all such modifications.

b. *The Flower.—A complete flower* (*fig.* 21) consists of the essential organs of reproduction enclosed in two particular envelopes which are designed for their protection. The essential organs are called the *Andrœcium* (*fig.* 22, *ec*, *ec*), and *Gynœcium*, *sti*. The floral envelopes are termed *Calyx* (*fig.* 21, *c*), and *Corolla*, *p*, *p*. The extremity of the peduncle or pedicel upon which the parts of the flower are placed, is called the *Thalamus* (*fig.* 22, *r*). The floral whorls or circles are situated on the thalamus, proceeding from without inwards in the following order:—1. Calyx, 2. Corolla, 3. Andrœcium, 4. Gynœcium.

The *Calyx* (*fig.* 21, *c*) is the whorl or circle of organs forming the outer envelope or covering of the flower. Its parts are called *sepals*, and these are generally green, and of a less delicate texture than those constituting the corolla.

The *Corolla* (*fig.* 21, *p*, *p*) is the whorl or whorls of leafy organs situated within the calyx, and forming the inner envelope of the flower. Its parts, which are called *petals*, are also commonly of other colours than green, and of a more delicate nature than those of the calyx.

The calyx and corolla are sometimes spoken of collectively under the name of *perianth*. This term is more particularly applied to Monocotyledonous plants, where the floral envelopes generally resemble each other, and are usually of other colours than green, *i.e. petaloid* in their nature. The Tulip may be taken as a familiar example.

The floral envelopes are also called the *non-essential* organs of the flower, because their presence is not absolutely necessary for the production of the seed. When both are present, as is commonly the case, the flower is said to be *dichlamydeous*; but sometimes there is only one floral envelope, as in the Goosefoot (*fig.* 24), when the flower is described as *monochlamydeous*, and the whorl which is present is then properly considered as the calyx, whatever be its colour or other peculiarity; but some botanists use the term *perianth* in this case, as will be explained hereafter in describing the

FIG. 21.

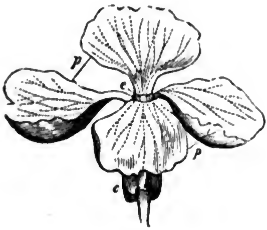


FIG. 22.

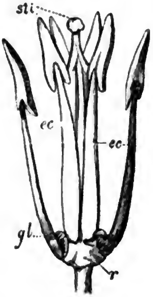


FIG 23.

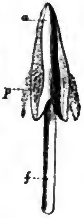


Fig. 21. Flower of Wallflower (*Cheiranthus Cheiri*). *c.* Calyx, composed of parts called sepals. *p. p.* Petals. *e.* Summit of the stamens, which enclose the pistil.——*Fig.* 22. Flower of Wallflower with the calyx and corolla removed, in order to show the essential organs of reproduction. *r.* Thalamus. *gl.* Glands. *ec, ec.* Stamens, of which there are six, four long and two short, the whole forming the andrœcium. *sti.* Stigma, the summit of the gynœcium.——*Fig.* 23. One of the stamens of the Wallflower. *f.* Filament. *a.* Anther. *p.* Pollen, which is being discharged from a slit in the anther.

calyx in detail. At other times, as in the Ash (*fig.* 25), both the floral envelopes are absent, when the flower is termed *naked* or *achlamydeous.*

The *Andrœcium* constitutes the whorl or whorls of organs situated on the inside of the corolla (*fig.* 22, *ec*, *ec*). Its parts are called *stamens.* Each stamen consists essentially of a case or bag, termed the *anther* (*fig.* 23, *a*), which contains in its interior a powdery, or more rarely waxy, substance, called the *pollen*, *p*. The pollen when ripe is discharged, as represented in the figure, through little slits or holes formed in the anther. These are the only essential parts of a stamen; but it generally possesses in addition a little stalk, called the *filament*, *f*, which then supports the anther on its summit. The staminal whorl is termed the *Andrœcium*, from its constituting the male system of Flowering plants.

FIG. 24.

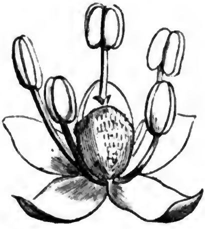


FIG. 25.

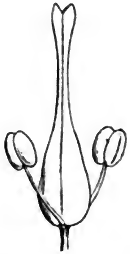


Fig. 24. Flower of Goosefoot (*Chenopodium*), with only one floral envelope (*monochlamydeous*).——*Fig.* 25. Flower of the Common Ash (*Fraxinus*), in which both floral envelopes are absent (*achlamydeous*).

The *Gynœcium* (or *Pistil*, as it is also called), the only remaining organ, occupies the centre of the flower (*fig.* 22, *sti*), all the other organs being arranged around it when these are present. It consists of one or more parts, called *carpels*, which are either distinct from one another, as in the Columbine (*fig.* 26, *c*), or combined into one body, as in the Poppy (*fig.* 27). This organ is termed the *gynœcium* from its constituting the female system of Flowering plants. Each carpel consists of a hollow inferior part, called the *ovary* (*figs.* 26, *o*, and 28, *d*), in which are placed one or more little bodies called *ovules* (*fig.* 28, *o*, *o*), attached to a part called the *placenta*, *p*; and of a *stigma*, or space

FIG. 26.

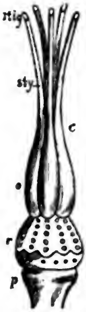


FIG. 27.

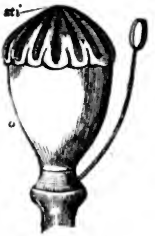


FIG. 28.

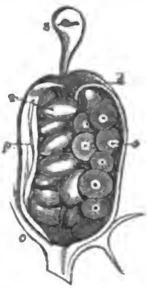


Fig. 26. Gynœcium of Columbine (*Aquilegia vulgaris*). *p*. Peduncle. *r*. Thalamus. *c*. Carpels, each with an ovary, *o*; style, *sty*; and stigma, *stig*.——*Fig.* 27. Gynœcium of Poppy (*Papaver*), with one stamen arising from below it. *o*. United ovaries. *sti*. Stigmas.——*Fig.* 28. Vertical section of the gynœcium of the Pansy (*Viola tricolor*). Remains of the calyx. *d*. Ovary. *p*. Placenta. *o*, *o*. Ovules. *s*. Stigma on the summit of a short style.

of variable size, which is either placed on the top of the ovary, as in the Poppy (*fig.* 27, *sti*), or it is situated on a stalk-like portion prolonged from the ovary, called the *style* (*fig.* 26, *sty*). But the only essential parts of the carpel are the ovary and stigma; the style being no more necessary to it than the filament is to the stamen.

The andrœcium and gynœcium are called *essential organs* because the direct action of both is necessary for the production of the seed. It frequently happens, however, that either the gynœcium or andrœcium is absent from a flower, as in the Willow (*figs.* 29 and 30), in which case the flower is termed *unisexual*; and it is still further characterised as *staminate* or *male* (*fig.* 29), or *pistillate*, *carpellary*, or *female* (*fig.* 30), according as it possesses one or the other of these organs.

c. *The Fruit and Seed.*—At a certain period the anther opens and discharges the pollen, which is then carried to the stigma by insects, or by the wind, by which the pistil is fertilised; and after the process of fertilisation has been effected, important changes take

FIG. 29.

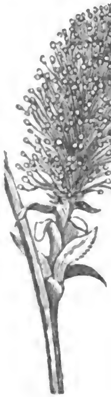


FIG. 30.

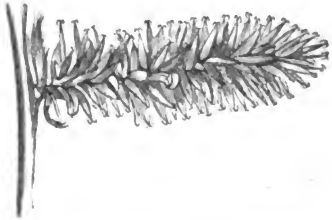


Fig. 29. Staminate flowers of a species of Willow (*Salix*) ——*Fig.* 30. Pistillate or carpellary flowers of the same.

place in it and the flower generally, the result being the formation of the fruit. Essentially the fruit consists of the mature ovary or ovaries, containing the impregnated or fertilised ovule or ovules, which are then termed *seeds*. But in some cases, besides the mature ovary or ovaries, other parts of the flower, as will be explained hereafter (see FRUIT), also become a portion of the fruit. The fruit, when perfectly formed, whatever be its composition, consists of two parts; namely, the *shell* or *pericarp*, and the seed or seeds contained within it.

The *seed*, as already noticed, is the fertilised ovule. It consists essentially of two parts: namely, of a *nucleus* or *kernel* (*fig.* 31, *emb*, *alb*), and *integuments*, *int.* The nucleus or kernel may either consist of the embryo alone, which is alone essential to it (*fig.* 11), or of the embryo (*fig.* 31, *emb*) enclosed in nourishing matter, called the *endosperm* or *albumen*, *alb*.

FIG. 31.

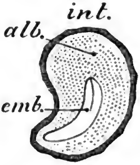


Fig. 31. Vertical section of the seed of a species of Poppy (*Papaver*). *int.* Integuments. *emb.* Embryo. *alb.* Albumen or endosperm.

After this general sketch of the different kinds of plants, and the compound organs which they respectively present, we are now able to proceed to the description of the elementary structures or building materials of which they are composed.

CHAPTER II.

ELEMENTARY STRUCTURE OF PLANTS, OR VEGETABLE HISTOLOGY.

Section 1. OF THE CELL AS AN INDIVIDUAL.

THE description of the elementary structure of plants is termed Vegetable Histology.

All the lower kinds of plants, as we have seen (pages 6–9), are made up of one or more membranous closed sacs called *cells*; and all other plants, however complicated in their appearance and structure, are also made up of these simple bodies variously modified and combined together. The cell is therefore the only elementary organ possessed by a plant; and hence necessarily requires our first and particular attention. We shall begin, then, by first describing the nature of the cell and its contents; and then pass on to a more detailed examination of its various forms, sizes, and structure.

I. Nature of the Cell and its Contents.—In the very earliest stage of a plant's existence—in, for example, the germinal vesicle of the higher plants—the cell consists only of a naked mass of a semifluid substance to which the name of *protoplasm* has been given, in the midst of which is a nucleus. In a few cases the cell remains in this condition, and is then termed a *primordial cell.* But as a general rule this protoplasm very shortly surrounds itself on the outside with a thin transparent membrane of *cellulose*—the *cell wall*—and in this condition three distinct parts can be observed in the cell (*fig.* 32): 1. the cell wall, *a*; 2. the internal proto-

Fig. 32.

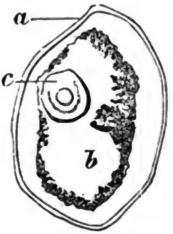


Fig. 33.

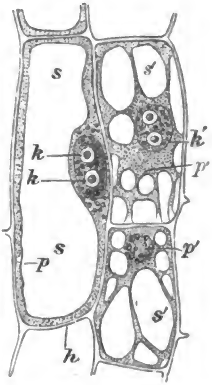


Fig. 32. A cell from the root of the Lizard Orchis (*Orchis hircina*). *a.* The cell-wall. *b.* The protoplasm contracted by alcohol. *c.* The nucleus with a nucleolus. After Thomé.——*Fig.* 33. Cells from the root of *Fritillaria imperialis*. *h.* Cell-wall. *k'.* Nucleus. *k, k.* Nucleus with nucleoli. *p.* Primordial utricle. *p'. p'.* Protoplasmic threads. *s, s.* Cavity filled with cell-sap. *s', s'.* Vacuoles. After Sachs.

plasm above mentioned, *b*; and 3. the nucleus, *c*, which is a rounder, denser portion, lying in the midst of the protoplasm. At first the protoplasm completely fills the cavity, but as the cell grows larger, drops (*vacuoles*) of a clear watery fluid called the *cell-sap* (*fig.* 33, *s′*, *s′*), make their appearance in it; and the nucleus, *k′*, is then suspended in the cell and connected to the protoplasm lining its inner wall, by slender threads or bands of the same substance, *p′*, *p′*. As the cell continues to enlarge, these vacuoles coalesce and form a single central sap-cavity, *s*, *s*, and the protoplasm is then confined to a thin layer lining the interior of the cell-wall—the *primordial utricle*, *p*, with the nucleus, *k*, *k*, showing as a denser mass in an enlargement of the protoplasm on one side. In the fully developed cell, therefore, we distinguish, 1. the cell-wall, 2. the protoplasm, 3. the nucleus, 4. the cell-sap.

Such is the nature of cells so long as they retain their active vital state, but after a time the protoplasm with its contained nucleus disappears, leaving the cell filled with air alone or water. Those cells only which contain protoplasm can grow, form chemical combinations, and produce new cells; while the latter, as the cells of the wood and bark, are of use only in virtue of their physical properties, as for example, giving firmness and acting as protecting envelopes to the living cells beneath, and in other ways.

1. THE CELL-WALL (*figs.* 32, *a*, and 33, *h*).—We have just seen that in a few cases the cell consists of nucleated protoplasm alone—or that, in other words, it has no cell-wall. As a general rule, however, this condition of things very shortly disappears; for the protoplasm, having elaborated molecules of cellulose ($C_6H_{10}O_5$), passes them to its outer surface, where they form a thin, colourless, transparent, continuous membrane, or *cell-wall*. As this membrane increases in age, it becomes thickened—as will be afterwards explained (page 41)—by the intussusception of new

molecules between the older ones, and eventually there are generally developed upon it various markings, which may either be protuberances as in the case of some pollen cells (*fig.* 54); or internal depressions, as may be seen in pitted and other kinds of cells (see pages 42–45). Those cells which are isolated, or on the surface of the plant, have the various markings on their outer or free surface, while those that are united to form tissues have them on the internal surface of their cell-wall. The former is termed centrifugal thickening; the latter centripetal thickening.

This cellulose is insoluble both in cold and in boiling water, also in alcohol, ether, and dilute acids, and almost insoluble in weak alkaline solutions. By the action of cold concentrated sulphuric acid the cellulose is broken down, and when diluted and boiled, converted first into dextrin, and then into grape-sugar. When cellulose is steeped in dilute sulphuric acid, and then treated with a solution of iodine, it is coloured blue. The cell-wall contains in addition to the molecules of cellulose a small quantity of mineral ash.

2. THE PROTOPLASM, as we have already seen, is the only part of the cell, and therefore of the whole plant, which is possessed of life; and the differences in the form, size and nature of cells is due to the vital energy which it is capable of exerting; this energy is frequently spoken of as *vital force.*

The appearance of protoplasm is as varied as is the form of the cells which it produces. It may be granular and opaque, or homogeneous and transparent; it may be almost fluid, or of the consistency of dough; or again it may be stiff, or even brittle: generally, however, it is of a light grey colour and more or less granular; but it is never a true fluid. In those cases where the protoplasm contains granules, it is formed of an outer thin layer called the *ectoplasm*, which is free from granules; and of an inner granular portion which is known as the *endoplasm.* According to Sachs, that matter only ought to be regarded as protoplasm which is perfectly transparent, and the granules where they occur are to be looked upon as 'probably finely divided, assimilated food-material.'

In most cases the presence of protoplasm may be readily detected by the use of reagents. Alcohol and weak acids cause it to shrink from the cell-wall (*fig.* 32); a solution of iodine colours it brown; while sugar and sulphuric acid cause it to assume a pink colour. Protoplasm is extremely rich in albuminoids, which chemically consist chiefly of carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus, the most distinctive element being that of nitrogen.

The *Primordial Utricle* (*fig.* 33, *p*), as has already been observed, is the thin layer of protoplasm which lines the cell-wall and forms the boundary of the central cavity filled with cell-sap. It is frequently so thin and transparent that it cannot be detected without the aid of reagents, which either colour it or cause it to separate from the cell-wall as mentioned above. By some authors the primordial utricle is differently characterised, and defined as the outer thin homogeneous layer or *ectoplasm* of the protoplasm. This is the sense in which it was essentially understood by Mohl.

3. THE NUCLEUS, which exists in all the cells of the higher plants, and is absent from only a few of the lower forms, is differentiated from the surrounding protoplasm as a denser portion of the same substance. It usually presents a more or less rounded outline, and contains one (*fig.* 32, *c*), two (*fig.* 33, *k'*, *k'*), or more, much smaller bodies, called *nucleoli*. It is always situated in, and more or less enclosed by, the protoplasm, as we have already seen, and never lies loose in the cell cavity. It is the more vitally active part of the protoplasm in which it is contained.

4. THE CELL-SAP is the watery fluid which is found in the interior of the cell; it contains dissolved or suspended in it all those food materials which are

necessary for the life and growth of the cell. In the earlier stages of the cell's life, as we have already seen, the cell-sap as a substance distinct from the protoplasm does not occur, but is diffused generally through it and the cell-wall, and it is only as the cell enlarges that it first appears in the form of drops (*vacuoles*) in the protoplasm (*fig.* 33, *s'*, *s'*), and which by ultimately coalescing form a single cavity filled with sap, *s*, *s*. Besides containing substances which are necessary to the life of the cell, it contains also many things which have been thrown out from the protoplasm as no longer serviceable. Of this nature are the crystals of calcium carbonate and calcium oxalate; hence the cell-sap may be regarded from one point of view as the food upon which the protoplasm lives, and from another as the reservoir into which it pours out certain of its waste products.

Besides the fluid cell-sap, there are other important cell-contents, some of which, such as *chlorophyll*, *starch*, *raphides*, and *aleurone grains*, now require description.

CHLOROPHYLL AND CHLOROPHYLL GRANULES.—Chlorophyll is the colouring material which gives to leaves their green appearance. Its chemical composition, owing to the great difficulty there is of obtaining it pure, is not accurately known; but there seems much reason to believe that it is closely allied to wax. It is not soluble in water, but is readily so in alcohol, ether, or benzole. By soaking leaves in any of these substances a beautiful green solution is obtained when viewed by transmitted light, but which is red when observed by reflected light. If a weak alcoholic solution of chlorophyll is shaken up with an excess of benzole, the mixture separates into two distinct layers, the upper one of benzole which is coloured bright green, and the lower one of alcohol which is coloured bright yellow; by which it would seem that chlorophyll is not a simple substance, but is a mixture made up of two or more colouring principles. Thus, according to Frémy, chlorophyll is composed of two colouring principles, one blue, called *phyllocyanin*, and the other yellow, termed *phylloxanthin.* But the more recent experiments of Michell, Stokes, Müller, Pringsheim, and others, render it probable that chlorophyll is even a more complex substance than believed by Frémy, as will be described hereafter when treating of the Physiology of Plants.

Chlorophyll does not commonly exist indiscriminately diffused throughout the interior of the cell, but is confined to special portions of the protoplasm which have been differentiated from the general mass. These portions of protoplasm are the so-called *chlorophyll granules* or *chlorophyll grains* (*figs.* 42 and 66, *chl*), or, as they are also termed, *chlorophyll bodies* and *chlorophyll corpuscles*; hence these structures are granules of protoplasm coloured green by chlorophyll. If a plant is grown in the dark these granules remain pale coloured; but if it be exposed to sunlight, they speedily become coloured green; hence light is necessary, with rare exceptions, for the formation of chlorophyll; and when so coloured they have the power of breaking up the carbon dioxide of the air or the water in which the plant is growing, and, returning the oxygen to the air, retain the carbon, which they are able to mix with the elements of water in such proportions as to build up a molecule of starch, and some other carbohydrates. This process of building up starch and other allied substances out of the carbon dioxide of the air or water has been termed *assimilation.*

It has just been said that chlorophyll is generally confined to the protoplasm forming the chlorophyll granules; this is true in all the higher plants, but there are some plants amongst the lower orders in which the green coloured portions form plates or spiral bands, as in *Spirogyra*; or the whole protoplasm, with the exception of the ectoplasm, may be capable of being coloured green, as in *Glœocapsa* and *Oscillatoria.*

Starch.—This substance is, with the exception of protoplasm, the most abundant and universally distributed of all the cell-contents, occurring, as it does, more or less, in all parenchymatous cells (*fig.* 34), except those of the epidermis. In its fully developed state it is, however, most abundant in the matured structures of plants, as the pith of stems, seeds, roots, and other internal and subterranean organs which are removed from the influence of light.

FIG. 34.

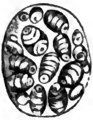


FIG. 35.

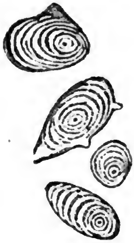


FIG. 36.

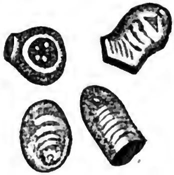


FIG. 37.

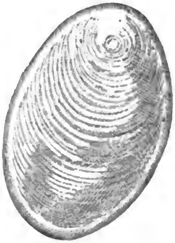


FIG. 38.

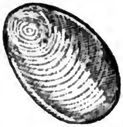


Fig. 34. Cell of the Potato containing starch granules.——*Fig.* 35. West-India Arrowroot (× 250).——*Fig.* 36. Sago meal (× 250).——*Fig.* 37. Tous-les-mois (× 250).——*Fig.* 38. Potato starch (× 250).

Starch is not only widely distributed through the different parts of a plant, but it also occurs in varying quantity in all classes of plants with the exception of the Fungi. West Indian Arrow-root (*fig.* 35), Sago (*fig.* 36), Tous-les-mois (*fig.* 37), and Potato starch (*fig.* 38) may be mentioned as familiar examples of starches derived from different plants.

When fully formed, starch is found floating in the cell-sap (*fig.* 34) in the form of colourless granules or grains, which are either distinct from one another as is usually the case (*fig.* 34), or more or less combined together so as to form compound granules (*see* page 33).

In form the separate granules are always spherical or nearly so in their earliest condition. In some cases this form is nearly maintained in their mature state, as in Wheat starch (*fig.* 39), but the granules frequently assume other forms, as ovate, elliptical, more or less irregular, club-shaped, or angular (*figs.* 34–40). Starch granules vary also extremely in size in different plants, and even in the same cell of any particular plant. The largest granules known appear to be those of Canna starch (*fig.* 37), or, as it is commonly termed, 'Tous-les-mois,' where they are sometimes as much as the $\frac{1}{300}$ of an inch in length; while the smallest granules, among which may be mentioned those of Rice starch (*fig.* 40), are frequently under $\frac{1}{3000}$ of an inch in length.

FIG. 39.

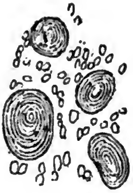


FIG. 40.

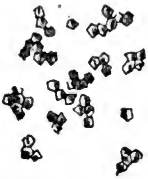


Fig. 39. Wheat starch (×250).——*Fig.* 40. Rice starch (×250).

Development of Starch.—Starch first makes its appearance as minute colourless granules in the interior of the chlorophyll grains when exposed to sunlight, as previously noticed at page 29. These primary starch granules, however, rarely grow to any considerable size, but are dissolved, chemically altered, and poured out into the sap, of which they then form a part. A part of this primary starch may be used by the protoplasm of the cell in which it is formed for the manufacture of its cell-wall, but by far the greater part is handed down from one cell to another till it arrives at particular parts of the plant, when it becomes reorganised and stored up for future use. In this latter state starch assumes its more characteristic appearance. Thus in a well-developed Potato granule (*fig.* 38), we may observe a roundish dark spot, termed the *nucleus* or *hilum*, which is commonly situated near one end of the granule; and surrounding this a variable number of faint lines which alternate with other darker ones, so that the whole presents the appearance of a series of more or less irregular concentric shells placed around a common point. The cause of these appearances has given rise to much discussion; thus at first sight it is almost impossible to help believing that the granule must have been built up in the same manner as a crystal, namely, by the deposition of fresh matter over the older, or, in other words, that the outer rings of the starch granule have been deposited over those which are more internal, and that therefore they are the youngest portion of the granule. But the observations of Nägeli have proved this not to be the case, for he has shown that the appearance of stratification in the starch granule is really due to the difference in the quantity of water which exists in the different parts of the granule, and he has proved that the outermost layer, instead of containing the greatest amount of water, as it ought to do if it was the youngest part of the granule, contains the least, while the hilum on the other hand is the most watery of all. Nägeli concluded from these observations that the growth of the starch granule was by intussusception of fresh particles of the starch-compound between those of an older date; and hence that the regular alternation of dense layers with more watery ones round a centre or hilum produces the peculiar appearances of starch granules. That the different layers vary in density may be at once proved by the action of polarised light, when each granule usually exhibits a black cross.

The starch granules of different plants vary very much in the character of their hilum, and in the distinctness and general appearance of their concentric lines, in the same way as they vary exceedingly in form and size when obtained from different sources; those, however, which are derived from the same plant are more or less uniform in appearance, so that a practised observer may distinguish under the microscope the different kinds of starch, and refer them to the particular plants from whence they have been derived.

Sometimes there is more than one hilum in a starch granule, and as growth then takes place round each, compound granules are formed.

Composition and Chemical Characteristics of Starch.—The starch granule consists of the true *starch-compound* and *water.* The starch-compound is again formed of two substances, which are intimately blended together, viz. *granulose* and *cellulose.* The granulose makes up by far the greater part of the starch-compound, being in the proportion of 95 to 5 of cellulose. It is capable of being dissolved out of the cellulose by saliva and dilute acids, and it is to this substance that the starch granule owes the violet-blue colour which it assumes when treated with a solution of iodine. The cellulose, on the other hand, being not soluble, is left behind as a skeleton, and is not coloured blue by the iodine solution.

Starch is composed chemically of carbon and the elements of water; it never occurs, however, naturally in a perfectly pure condition, but always contains a very small quantity of mineral constituents, and also a certain proportion of the peculiar secretions of the plant from whence it has been derived. Starch is insoluble in cold water, alcohol, ether, and oils. By the action of boiling water it swells up and forms a mucilage or paste; and if to this when cooled iodine be added, a deep blue colour is produced. If starch be exposed to a temperature of about 320° F. for a short time, it is converted into a soluble gummy substance, called *dextrin* or *British gum.*

RAPHIDES.—This name is now more generally applied to all inorganic crystals of whatever form which

FIG. 41.

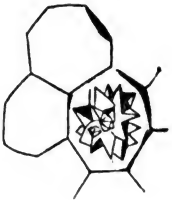


FIG. 42.

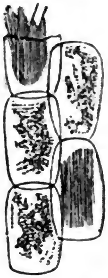


FIG. 43.

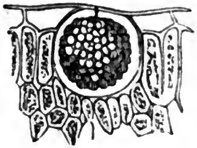


Fig. 41. Conglomerate raphides of the Beet.——*Fig.* 42. Acicular or true raphides of a species of *Rumex.* Two of the cells contain raphides, and three chlorophyll granules.——*Fig.* 43. Cystolith, from *Parietaria officinalis.* After Henfrey.

are found in the cells of plants, although the term *raphides* (which is the Greek for needles) was originally given to those only that were shaped like a needle (*fig.* 42). Raphides have been found more or less in nearly all orders of plants, and in all their organs; generally, however, they are most abundant in the stems of herbaceous plants, in the bark of woody plants, and in leaves and roots. These crystals are usually found in the cavities of the cells, but they also occur in their walls, as the cell-walls of the Coniferæ and Gnetaceæ.

When found in the interior of cells, they either occur singly, as in the inner bark of the Locust tree, or far more commonly there are a number of crystals in the same cell. In the latter case they are usually either placed side by side, as in the stem of *Rumex* (*fig.* 42); or in groups radiating from a common point, so as to assume a clustered or conglomerate appearance, as in the stem of the common Beet (*fig.* 41). The former have been termed *acicular* or *true raphides*, and the latter *conglomerate raphides* or *sphæraphides.*

In some plants, especially in the Urticaceæ, there may be frequently observed just beneath the surfaces of the leaves, or sometimes more deeply situated, peculiar structures, to which the name of *Cystoliths*, or *Lithocysts*, has been applied. These consist of an enlarged cell containing commonly a globular (*fig.* 43), or somewhat club-shaped mass of crystals suspended from the top by a kind of stalk formed by an ingrowth of the cell-wall, upon which the crystals are deposited.

Crystals of various composition have been described as occurring in different plants, but more accurate observations show that all the crystals hitherto found are composed of calcium carbonate, as those in the cystoliths, and in some of the lower Fungi; or of calcium oxalate. The latter salt crystallises in two forms according to the proportion of water it contains. Thus, in the one case, when the crystals contain six equivalents of water of crystallisation, they form octahedra, as in the conglomerate raphides; and, on the other hand, when there are only two equivalents of water of crystallisation, then bundles of acicular crystals are produced.

CRYSTALLOIDS, ALEURONE GRAINS, AND GLOBOIDS.—Besides the inorganic crystals just described, it frequently happens that some of the protoplasmic matter in the cells, more generally in those of the endosperm and cotyledons of ripe seeds—that is, in those cells in which reserve food material is stored up—assumes a crystalline form and becomes cubical, octahedral, tetrahedral, rhomboid, &c. (*fig.* 44). These are not however true crystals, as is seen by their angles not being very clearly defined by the action of various reagents, such as dilute caustic potash, which causes them to swell up and increase very much in volume. These crystalline masses are known as *crystalloids* or *proteine crystals.* They are readily seen when a transverse section of the albumen or endosperm of the seed of the Castor-oil plant is placed in dilute glycerine and water (*fig.* 44).

In the cells again of the endosperm and cotyledons of ripe seeds we have, in addition to starch and oily matter, small roundish and colourless albuminous grains, which are termed *proteid* or *aleurone grains.* They are especially abundant in oily seeds, as in those of the Castor-oil plant (*fig.* 44), where they appear to replace starch; but in those seeds where starch is abundant, these grains may be seen between the starch-grains, as in the Pea (*fig.* 45, *a*, *a*). In these grains the crystalloids just described are frequently found im-

FIG. 44.

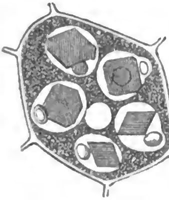


FIG. 45.

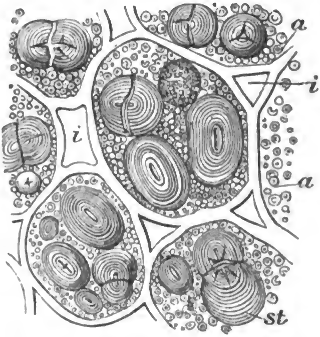


Fig. 44. Cell of the endosperm or albumen of the seed of the Castor-oil plant (*Ricinus communis*) in dilute glycerine, showing large transparent proteid or aleurone grains, with crystalloids and rounded globoids imbedded in them. After Sachs.——*Fig.* 45. Cells of a cotyledon of the common Pea (*Pisum sativum*). *a. a.* Aleurone grains. *st.* Starch granules. *i, i.* Intercellular spaces. After Sachs.

bedded, and also peculiar small round bodies, which are composed of double phosphate of calcium and magnesium, termed *globoids* (*fig.* 44).

The aleurone grains and crystalloids are evidently reservoirs of protein, to be used when growth becomes active in the process of germination, in the same way that starch and oily matters are reservoirs of hydrocarbons for use in a like manner. Aleurone grains are insoluble in alcohol, ether, benzole, or chloroform, but soluble in water. They are coloured brown by iodine, and other reagents show that they are of an albuminoid nature.

II. Forms and Sizes of Cells.—Having now described the nature of cells and their contents, we proceed to give a detailed account of the various forms and sizes which they are found to assume in different plants, and in the various parts of the same plant.

FIG. 46.

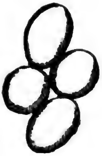


FIG. 47.

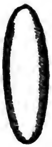


FIG. 48.

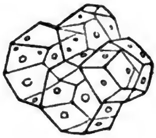


FIG. 49.

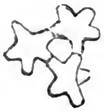


Fig. 46. Rounded cells.——*Fig.* 47. Oblong or oval cell.——*Fig.* 48. Polygonal cells in combination; these cells are pitted.——*Fig.* 49. Stellate cells.

1. *Forms of Cells.*—Cells are of various forms; thus, in the first place, when growth is uniform, or nearly so, on all parts of the cell-wall, we have *spherical* or *rounded* cells (*fig.* 46); but when it is greater at the two extremities than at the sides, the form is *oval* or *oblong* (*fig.* 47). In the above cases, also, the cells are almost, or entirely, free from pressure. But under other circumstances, in consequence of the mutual pressure of surrounding cells, they become *polygonal* in form (*fig.* 48), the number and the regularity or

irregularity of the angles depending upon the number and arrangement of the contiguous cells.

Secondly, when the growth is nearly uniform on all sides of the cell-wall, but not equally so at all points of its surface, we have cells which maintain a rounded form in the centre, but with rays projecting from them in various directions, by which they acquire a more or less star-like, or irregular, appearance. Hence such cells are *stellate* (*fig.* 49), or *irregular* in form (*fig.* 83, *c*).

FIG. 50.

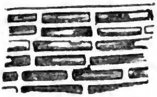


FIG. 51.

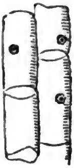


FIG. 52.

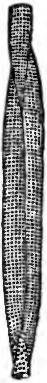


FIG. 53.

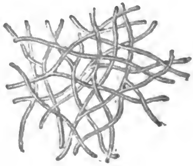


Fig. 50. Tabular cells.——*Fig.* 51. Cylindrical cells. The small rounded body in the interior of three of these cells is the nucleus. ——*Fig.* 52. Elongated fusiform cells.——*Fig.* 53. Fibrilliform cells.

Thirdly, when the growth takes place chiefly in one direction, we have cells which are elongated, either horizontally or vertically. Among the forms resulting from an extension of the cell in a horizontal direction, we have *tabular* cells (*fig.* 50), that is, six-sided flattened cells, with the upper and lower surfaces parallel, or nearly so. Of those cells which are extended in length or vertically, we have such forms as the *cylindrical* (*fig.* 51) and *fusiform* (*fig.* 52); and these by the mutual pressure of contiguous cells. often become *prismatic.* In the Fungi and Lichens we have a very marked form of cell. This is thin-walled and very long and thread-like, and either simple or branched. These cells are termed *fibrilliform* (*fig.* 53). (See page 47.)

The cells, when in combination with other cells so as to form a tissue, are generally bounded by more or less flattened (*figs.* 50 and 51), or rounded surfaces (*fig.* 46); but when in combination also with the vessels of the plant, so as to form what are called the *fibro-vascular bundles*, they are elongated, and have pointed extremities (*fig.* 67). These variations in the condition of the cells lead to corresponding differences in their arrangement; thus, in the former case, the cells (*fig.* 51) are placed one upon another, or side by side (*fig.* 50); while in the latter their tapering extremities overlap each other, and become interposed between the sides of the cells which are placed above and below them (*fig.* 69). From this circumstance cells have been divided into *parenchymatous* and *prosenchymatous*; parenchymatous being the term applied to those cells which are placed end to end or side by side; and prosenchymatous to those which are attenuated, and overlap one another when combined together to form a tissue. Another distinction commonly observed between parenchymatous and prosenchymatous cells arises from the condition of their cell-walls; thus, those of parenchymatous cells are usually thin (*fig.* 51), while those of prosenchymatous cells are more or less thickened (*figs.* 67 and 68). These latter cells are commonly termed *fibres.*

When cells are so placed as to be uncombined with other cells, or with the vessels of the plant, or but partially so, they are more or less unrestrained in their development; but even in such circumstances, as in their combined state, their typical form is to be more or less rounded. This form is, however, rarely maintained as they grow older, although instances of such occur in many of the lower Algæ (*fig.* 1); in pollen cells (*fig.* 54); and in spores; but more frequently, in such cases, the cells assume a more or less elongated form and become oblong or cylindrical. In such cells, again, we frequently find that certain points of the cell-wall acquire a special development (see page 26), and become elevated from its general surface as little papillæ (*fig.* 54), warty projections, or cilia (*fig.* 55), or are prolonged into tubular processes, or branched in various ways, as in the hairs of plants (*figs.* 92 and 93), &c.

2. *Sizes of Cells.*—The cells vary much in size in different plants, and in the various parts of the same plant. The parenchymatous cells, on an average, vary from about $\frac{1}{250}$ to $\frac{1}{1200}$ of an inch in diameter; others again are not more than $\frac{1}{5000}$; while in some cases they are so large as to be visible to the naked eye, being as much as $\frac{1}{50}$ or even $\frac{1}{30}$ of an inch in diameter. The largest occur in the pith of plants, in succulent parts, and in water plants.

FIG. 54.

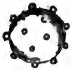


FIG. 55.

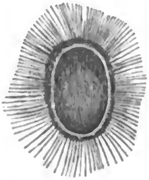


Fig. 54. Spherical pollen cell with small projections or papillæ on its outside.——*Fig.* 55. Ciliated cell.

The dimensions of prosenchymatous cells generally afford a striking contrast to those of the parenchymatous, for while we find that their transverse diameter is commonly much less, averaging about $\frac{1}{1500}$ of an inch, and frequently not more than $\frac{1}{3000}$, they become much more extended longitudinally, some having been measured as much as $\frac{1}{4}$ of an inch or more long; but as a general rule they vary from about the $\frac{1}{40}$ to the $\frac{1}{12}$ of an inch in length.

Those cells again which are more or less unrestrained in their development are frequently even far more extended in length. Thus, the cells of which cotton is formed are sometimes as much as one or two inches long; while in some of the Cryptogamous water plants, as *Chara*, the cells are also much elongated.

III. GENERAL PROPERTIES AND STRUCTURE OF THE CELL-WALL.—As has been already stated (page 25), the cell-wall of young cells is very thin, colourless, transparent, smooth, and free from any openings or visible pores, so that each cell is a perfectly closed sac. The cell-wall, however, although free from visible pores, is readily permeable by fluids. We now proceed to a more detailed description of the general properties and structure of the cell-wall.

As the cell-wall increases in age it becomes thickened, as we have seen (page 26), by the intussusception or incorporation of new matter into its substance, and then alterations occur by which it ultimately becomes variously marked and sculptured on its inner surface. A section of one of these cells gives an appearance as if the walls had been formed by concentric layers of cellulose with branching capillary tubes or canals stretching from the cavity of the cell to its periphery (*fig.* 57). The irregular ringed appearance is due to the difference in the degree of hydration, such as was seen in the case of the starch granule (see page 32); while the canals are true passages, which have been caused by the passage of the sap during the life of the cell preventing the deposition of cellulose. In these cells the membrane has been still further changed by the conversion of the cellulose into lignin. It is to these two conditions that the firmness of the wood of plants and hardness of the stones of many fruits are due, and hence the name *sclerenchymatous* (from a Greek word signifying hardness) has been given to such cells.

Pitted or Dotted Cells.—When the cell-wall has thus become thickened, it commonly presents a greater or less number of dots or slits of various kinds (*figs.* 56, and 57, *e*, *e*), instead of being smooth and homogeneous, as in its young condition. These dots and slits were formerly considered as actual openings in the walls of the cells, and hence such cells were called *porous cells*; but, when carefully examined, it may be readily discovered that these markings are caused by canals which run from the cavity of the cell to the inside of its wall, and are closed (at least, always in their young state) by the originally thin membrane of which it is at such points composed (*fig.* 57, *a*, *a*), and thus give to the part of the cell-wall in which they are found, when viewed under the microscope by transmitted light, a more transparent appearance than that possessed by the thickened membrane surrounding them. Such cells are, therefore, improperly called *porous*, and hence are now correctly termed *pitted cells*.

FIG. 56.

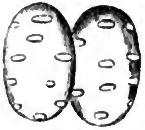


FIG. 57.

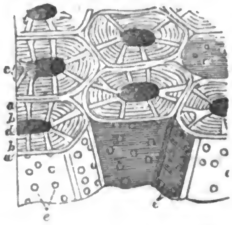


Fig. 56. Pitted cells.——*Fig.* 57. Thick-walled cells from the fruit of a Palm. *a*, *a*. Cell-walls. *b*, *b*. Concentric rings. *c*. Canals extending from the cavity to the inside of the wall of the cell. *d*. Cavity of the cell. *e*, *e*. External pitted appearance. From Unger.

Cells with Bordered Pits.—In the cell-walls of the wood-cells of certain trees, &c., we find, in addition to the ordinary pits, large circular discs which encircle them, so that each pit looks as if it had a ring surrounding it (*fig.* 58); hence such cells have been termed *cells with bordered pits.* This appearance is produced by circular patches of the cell-wall remaining thin after the general thickening has commenced and the rim growing obliquely inwards, leaving only a narrow orifice in the centre; or, in other words, the opening of the canal into the interior of the cell is narrow, while the outer opening by the cell-wall is broad (*figs.* 59, *a*, *b*, and *c*). As these thickenings occur always in twos on each side of the cell-wall, they appear as two watch-glasses would do if placed rim to rim, and separated by a thin sheet of paper. To carry out the comparison, however, completely, the watch-glasses must be supposed to be perforated in their centres (*fig.* 59). The central lighter spot when examined by transmitted light is caused by the light having to pass only through the thin membrane (*fig.* 59, *w*), while the darker colour of the border is caused by the light having to pass through the thicker substance of the rim. It frequently happens that the membrane between the adjoining cells becomes absorbed so that direct communication takes place between them.

FIG. 58.

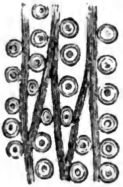


FIG. 59.

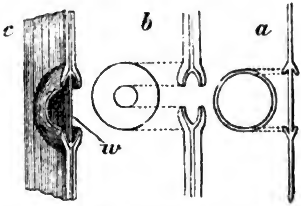


Fig. 58. Bordered pits of the wood-cells of the Pine, with a single row of discs in each cell.——*Fig.* 59. Bordered pits of wood cells of the Pine (diagram). *a.* Young stage with membrane. *b.* Older stage where the membrane has been absorbed. *c.* Semi-profile view, showing position of membrane, *w.* After Sachs.

These bordered pits occur either in single rows (*fig.* 58), or in double or triple rows. In the latter cases the bordered pits may be either on the same level, as is more commonly the case, or at different levels, and, therefore, alternate with each other.

Cells presenting such an appearance are of universal occurrence in the wood of the Coniferæ and other Gymnosperms, where they are also most distinctly observed. But somewhat similar bordered pits may also be not unfrequently observed in many vessels and elsewhere.

Fibrous Cells.—It frequently happens that the thickening of the cell-wall (instead of taking place so as to give the appearance of a perforated membrane, and which gives rise to the pitted cells just described), forms delicate threads or bands of varying thickness called *fibres*, which assume a more or less spiral direction upon its inner surface (*figs.* 60–62), and thus give rise to what are called *fibrous cells.* Such cells occur in various plants and parts of plants; more especially in the integuments of some seeds and fruits, as those of *Salvia*, in the spore-cases of certain Flowerless plants, and in the inner lining of all anthers.

FIG. 60.

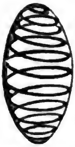


FIG. 61.

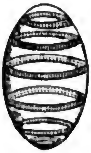


FIG. 62.

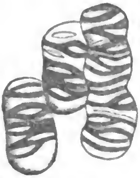


FIG. 63.

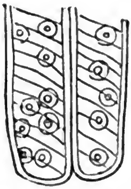


Fig. 60. Spiral cell.——*Fig.* 61. Annular cell.——*Fig.* 62. Reticulated cells.——*Fig.* 63. Wood-cells of the Yew (*Taxus baccata*). After Mohl.

These fibrous cells also present certain differences of arrangement in the distribution of their fibres. Thus in some cells the fibre forms an uninterrupted spiral from one end to the other (*fig.* 60); such are termed *spiral cells.* In other cases the fibre is interrupted at various points, and assumes the form of rings upon the inner surface of the cell-wall (*fig.* 61); hence such cells are called *annular*. Instances also occur even more frequently, in which the fibres are so distributed as to produce a branched or netted appearance (*fig.* 62); in which case the cells are termed *reticulated*. In some cases, again, as in the Yew (*fig.* 63), we find a spiral fibre or fibres developed in addition to the pits; such cells have been called *tracheïdes*.

Section 2 OF THE KINDS OF CELLS AND THEIR CONNEXION WITH ONE ANOTHER.

WE have already seen, that if the cells are of such forms that when combined together they merely come in contact with one another by more or less flattened surfaces, they are called *parenchymatous*; but that when elongated and pointed at their ends, so that in combination they overlap one another, they are termed *prosenchymatous*. But, besides these elongated prosenchymatous cells, other lengthened tubular organs are also found in plants, which are termed vessels. (*See* Vessels, page 49.) By the combination of the different kinds of cells and vessels, we have various compound structures formed which are called Tissues; the most important and the most abundant of them all is parenchyma, which must, therefore, be first alluded to.

1. PARENCHYMA.—This is composed of comparatively thin-walled cells, whose length does not generally exceed their breadth, or in which the proportion of the two diameters does not vary to any remarkable extent. There are several varieties of parenchyma, depending chiefly upon the forms of the component cells, and their modes of combination, of which the following are the more important:—*Round* or *Oval Parenchyma* (*figs.* 46 and 64): this is formed of rounded, or more or less oval cells, with small spaces between them. It com-

monly occurs in succulent plants, and generally in those parts where the tissues are of a lax nature. --*Stellate* or *Spongiform Parenchyma*: this consists of stellate cells (*fig.* 65), or of cells with an irregular outline produced by projecting rays, and in contact only by the extremities of such rays, so as to leave large irregular spaces between them (*fig.* 83, *c*). It occurs commonly in the tissue on the under surface of most leaves; and frequently in the air-passages of plants.—*Regular* or *Polyhedral Parenchyma*: this is formed of polyhedral cells, the faces of which are so combined as to leave no interspaces (*fig.* 48). It is commonly found in the pith of plants.—*Elongated Parenchyma*: this is composed of cells elongated in a longitudinal direction so as to become fusiform, cylindrical or prismatic, and closely compacted. It occurs frequently in the stems of Monocotyledonous plants.—*Tubular Parenchyma* is that which consists of tabular closely adherent cells. It is found in the epidermis and

FIG. 64.

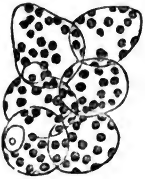


FIG. 65.

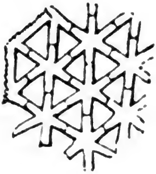


FIG. 66.

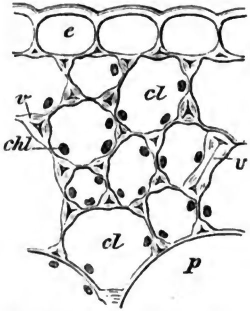


Fig. 64. Round or oval parenchyma. In two of the cells a nucleus may be seen.——*Fig.* 65. Stellate or spongiform parenchyma, composed of stellate cells with three-cornered intercellular spaces. ——*Fig.* 66. Transverse section of the petiole of a species of *Begonia*. *e*. Epidermis with cuticle above and hypoderma below, the latter formed of collenchymatous cells, *cl*, *cl*, with thickened angles, *v*, *v*. *chl*. Chlorophyll granules. *p*. General parenchyma, below hypoderma. After Sachs.

other external parts of plants (*fig.* 66, *e*). A variety of this kind of parenchyma is called *muriform*, because the cells of which it is composed resemble in their form and arrangement the courses of bricks in a wall (*fig.* 50); this occurs in the medullary rays of the wood of Dicotyledonous plants.

Such are the commoner varieties of parenchyma, all of which are connected in various ways by transitional forms; but other special kinds also occur. Thus, in the tissue which is placed below the epidermis of plants, which has been termed the *hypoderma*, we sometimes find the parenchyma composed of cells which are especially thickened at their angles (*fig.* 66, *cl*, *cl*); and these thickened portions swell up considerably when such cells are placed in water. This kind of parenchyma is called *collenchyma*; it never becomes lignified. Another variety of parenchyma is termed *sclerenchyma*; this consists of cells which have become much hardened by thickening layers and lignified.

In some of the lower orders of plants there is also a kind of tissue present which is quite as distinct from ordinary parenchyma as this is from prosenchyma and the tissues formed by the vessels of plants. To this the names of *Tela contexta* and *Interlacing fibrilliform Tissue* have been given. It occurs in the Fungi (*figs.* 3 and 4), and Lichens, and consists of very long thread-like cells, or strings of cells, simple or branched, with either thin, soft, readily destructible walls, as in Fungi; or dry and firm ones, as in Lichens; the whole inextricably interwoven or entangled with each other so as to form a loose fibrilliform tissue (*fig.* 53). It is this tissue which is also commonly known under the name of *hyphæ* or *hyphal tissue*, which constitutes, as a general rule, the vegetative portion of all Fungi and Lichens; and in the larger Fungi this hyphal tissue forms a more compact structure at particular parts, as on their surface, where it forms a kind of skin, and then constitutes what is termed *pseudo-parenchyma*.

The entire structure of the lower orders of plants, or Thallophytes, such as the Algæ, Fungi, and Lichens, consists of parenchyma; hence such plants are termed Cellular Plants; while those orders above them, which, as a general rule, contain vessels and prosenchymatous wood-cells in addition to parenchymatous cells, are called Vascular Plants (*see* page 9). In these higher orders of plants, parenchyma constitutes all the soft and pulpy parts. Parenchyma is connected by various intermediate conditions with *prosenchyma*, which must now be described.

FIG. 67.

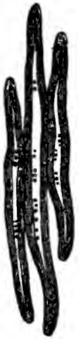


FIG. 68.

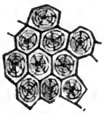


FIG. 69.

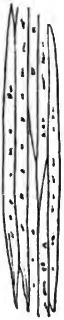


Fig. 67. Prosenchymatous or wood-cells.——*Fig.* 68. Transverse section of prosenchymatous cells, showing the thickness of their walls.——*Fig.* 69. Prosenchymatous cells in combination.

2. PROSENCHYMA.—The most perfect form of prosenchyma is that commonly termed *Woody Tissue*, or *Woody Fibre*. This tissue consists of very fine cells, elongated and tapering to their extremities, their walls being much thickened (*fig.* 67), and when in contact with one another overlapping by their pointed ends, so that they are firmly compacted together and leave no interspaces (*fig.* 69).

We distinguish two kinds of woody tissue as follows:—1. *Woody Tissue.* This, the ordinary kind of woody tissue, is composed of prosenchymatous cells or *fibres*, of moderate length and lignified (*fig.* 67). A transverse section of these cells shows the thickening matter of their walls arranged in concentric layers, and which are often so numerous as to almost obliterate their cavity (*fig.* 68). This kind of tissue occurs in the wood of most trees, except that of the Gymnospermous plants, and in the veins of certain leaves and some other appendages of the axis.—2. *Woody Tissue of the Liber.* This consists of prosenchymatous cells much longer than ordinary wood-cells, with very thick walls, and owing to their not being lignified, they are softer, tougher, and more flexible; hence these are regarded as a peculiar kind of cell, and have received the distinctive name of *Liber-cells*, from their common occurrence in the inner bark or liber of Dicotyledonous stems. Such cells are also termed *bast-fibres*, and the tissue formed of them *bast-tissue*, because the inner bark is also commonly termed *bast.* Besides the common occurrence of this tissue in the liber, it also occurs as a constituent of the *fibro-vascular bundles* of Monocotyledonous stems; and of the fibrous coats of fruits, and in other parts.

A third kind of woody tissue is also sometimes distinguished under the name of *Disc-bearing Woody Tissue.* This is composed of *cells with bordered pits* (*figs.* 58 and 59), and which have been already described on page 43.

The different kinds of woody tissue are commonly associated with other tubular organs, but which are larger than the prosenchymatous cells of which the woody tissues are composed. These constitute the vessels of plants, and must now be described.

3. VESSELS.—The essential character of a vessel is that it is composed of several cells, which are united end to end, and the septa, dividing them, more or less completely absorbed. There are several varieties of

vessels, which are known as *pitted*, *spiral*, *annular*, *reticulated*, and *scalariform*, the characters of which depend upon the component cells out of which they have been formed, and which have been already described. They contain air or water.

But besides these vessels we have also other varieties, which are commonly distinguished under the names of ***sieve-tubes*** or ***sieve-vessels***, ***laticiferous vessels***; and *vesicular* or *utricular vessels.* These are closely related to each other from the nature of their contents, their chief function being to act as reservoirs of nutrient fluids, and also as carriers of such fluids to the parts of plants where they are required.

FIG. 70. FIG. 71. FIG. 72. FIG. 73.

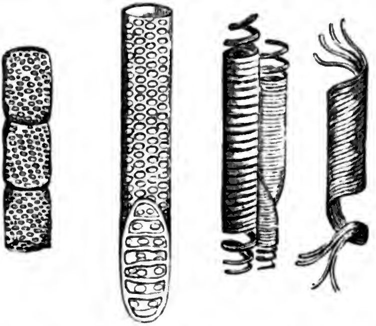


Fig. 70. Row of pitted cells.——*Fig.* 71. Pitted vessel terminating obliquely, and showing that the partition wall has been incompletely absorbed.——*Fig.* 72. Simple spiral vessels.——*Fig.* 73. Compound spiral vessels.

a. *Pitted or Dotted Vessels.*—A pitted vessel is formed from a row of cylindrical pitted cells placed end to end (*fig.* 70), the intervening partitions of which have become more or less absorbed, so that their cavities communicate and form a continuous canal (*fig.* 71). Pitted vessels may be commonly found in the wood of Dicotyledons, where they are mixed with the ordinary wood-cells, but are much larger than these; indeed, these vessels are generally among the largest occurring in any tissue.

It sometimes happens that when a pitted vessel has lost its fluid contents the neighbouring parenchymatous cells push bladder-like portions of their membrane through pores in its wall, and then multiply by divisions and form a cellular mass which may completely fill it—to this intracellular tissue the name of *tyloses* has been given. It may be well observed in the wood of the Oak.

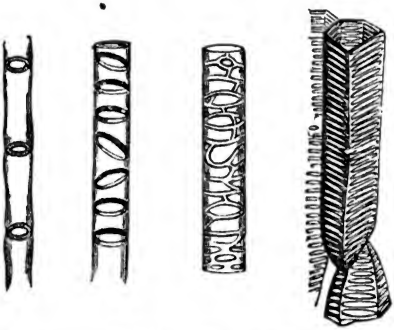
b. *Spiral Vessels.*—This name is applied to vessels with tapering extremities, having either one continuous elastic spiral fibre running from end to end, as is commonly the case (*fig.* 72), or two or more fibres (*fig.* 73) running parallel. When spiral vessels come in contact they overlap more or less at their ends (*fig.* 72), and frequently the membrane between their cavities then becomes absorbed so that they communicate with each other. Spiral vessels occur in the sheath surrounding the pith of Dicotyledons, and in the fibro-vascular bundles of Monocotyledons, and in some of the Cormophytes, as the Lycopodiaceæ. They also exist in the petiole and veins of leaves, and in all other organs which are modifications of leaves, as bracts, sepals, petals, &c. In size they vary from the $\frac{1}{300}$ to $\frac{1}{3000}$ of an inch in diameter, averaging about the $\frac{1}{1000}$.

c. *Annular Vessels.*—In these vessels the fibre is arranged in the form of rings more or less regularly arranged upon their inner surface (*figs.* 74 and 75). In size they vary from about $\frac{1}{400}$ to $\frac{1}{800}$ of an inch in diameter. Annular vessels occur especially in the fibro-vascular bundles of the stems of soft, rapidly growing herbaceous plants among Dicotyledons; also in those of Monocotyledons; and in those of some Cormophytes. In the latter they exist especially, and of a very regular character in the Equisetaceæ (*fig.* 74).

d. *Reticulated Vessels.*—In these vessels the convolutions are more or less irregular, so that they assume a branched or netted appearance (*fig.* 76). These vessels are generally larger than the annular, and of much more frequent occurrence. They are found in similar situations.

e. *Scalariform Vessels.*—The peculiar appearance of these vessels is owing to their walls being marked by transverse bars or lines, arranged over one another like the steps of a ladder, whence their name (*fig.* 77). These vessels are sometimes cylindrical tubes like the other kind, as in the Vine and many other Dicotyledonous plants; but in their more perfect state, scalariform vessels assume a prismatic form, as in Ferns (*fig.* 77), of which they are then especially characteristic, though also found elsewhere.

FIG. 74. FIG. 75. FIG. 76. FIG. 77.



Figs. 74 and 75. Annular vessels.——*Fig.* 76. Reticulated vessel.——*Fig.* 77. Prismatic scalariform vessels of a Fern.

f. *Sieve-tubes or Sieve-vessels.*—These are vessels in which the thickening of the cell-walls of their component cells does not take place uniformly over their whole surface, but only at the ends of the cells, that is, where they are in contact with others of a similar nature. At these ends it forms a kind of network, sculptured in relief as it were on the wall (*fig.* 78, *q*); and when in such cases the unthickened part of the walls of contiguous cells becomes absorbed so that their cavities become continuous, we have formed what are commonly known as *sieve-tubes* or *sieve-vessels.* They are also sometimes termed *bast-vessels.* Some have also sieve-like openings through their side-walls (*fig.* 78, *si*).

FIG. 78.

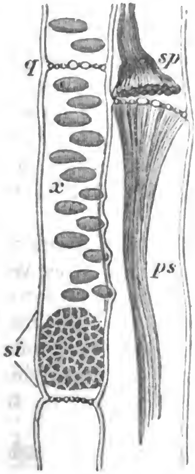


FIG. 79.

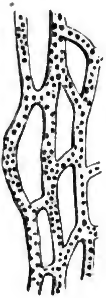


Fig. 78. Young sieve-tubes or sieve-vessels from the longitudinal section of the stem of *Cucurbita Pepo.* *q.* Transverse view of the sieve-like partition walls. *si.* Sieve-plate on the side-wall. *x.* Thinner parts of the side-wall. *ps.* Contracted protoplasmic contents, lifted off the transverse septum at *sp.* After Sachs.——*Fig.* 79. Laticiferous vessels.

These vessels are very constantly present in the inner bark of Dicotyledons. If the partition walls between the component cells are not really perforated, but only thickened in a sieve-like manner, the name of *sieve*, *lattice*, or *clathrate*, is applied to such cells.

g. *Laticiferous Vessels.*—These consist of long branched tubes lying in no definite position with regard to the other tissues (*fig.* 79), and anastomosing or uniting freely with one another like the veins of animals, from which peculiarity they may be at once distinguished from the other vessels of plants. A common size is the $\frac{1}{1400}$ of an inch in diameter. They derive their name from containing a fluid called *latex*, which when exposed to the air becomes milky, and is either white, as in the Dandelion and many other plants; or yellow, as in the Celandine; or it may assume other colours. The latex has a number of granules or globules floating in it, which are composed of caoutchouc, or analogous gum-resinous matters, albuminoids, &c. Laticiferous vessels occur especially in the inner bark of Dicotyledons, and in the petioles and veins of leaves. They are also to be found in the fibro-vascular bundles of Monocotyledons and all parts which are prolonged from them.

Besides the above more common characteristics of laticiferous vessels, there are numerous other varieties; indeed, from the very great variety in structure, contents, and position of these vessels, and the many and various transitions between them and vesicular vessels, now to be described, Sachs has proposed that these laticiferous and vesicular vessels should be included under the common name of *latex-sacs*.

h. *Vesicular Vessels.*—These resemble laticiferous vessels in one particular, as they contain latex (which, however, is clear or milky, and always contains true raphides); while, on the other hand, they are unbranched and analogous to sieve-tubes in form, consisting as they do of long broad cells with sieve-like septa. They were first noticed by Hanstein in the scales of the bulb of *Allium*, and have since been observed in the leaves and other parts of Monocotyledonous plants, and in some Dicotyledons.

We have now described the different kinds of cells, and the modifications they undergo, and the combinations which take place between them so as to form vessels. The different kinds of vessels and woody tissues are more or less combined together, and have always a tendency to develop and arrange themselves in longitudinal bundles in all parts of the plant where they are found, and thus they may be readily distinguished from the parenchyma in which they are placed, both in their form and mode of elongation. Hence we speak of the tissue formed of these bundles under the name of *Fibro-vascular Tissue*, or the *Fibro-vascular*, or *Longitudinal System*; to distinguish it from the ordinary cellular tissue, which constitutes the *Parenchymatous* or *Horizontal System*.

FIG. 80.

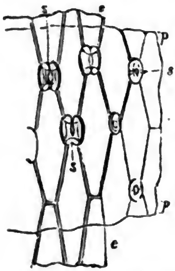


FIG. 81.

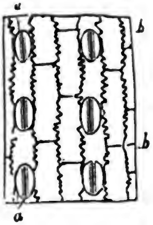


FIG. 82.

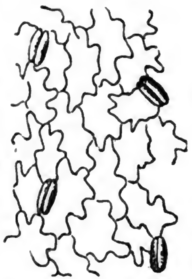


Fig. 80. Epidermal tissue from the leaf of the Iris (*Iris germanica*). *p, p.* Cuticle. *s, s, s.* Oval stomata. *e, e.* Epidermal cells. After Jussieu.——*Fig.* 81. Epidermis of the Maize. *a, a.* Oval stomata. *b, b* Zigzag reticulations formed by the sides of the cells.——*Fig.* 82. Sinuous epidermis with oval stomata, from the garden Balsam.

4. EPIDERMAL TISSUE.—In Cormophytes and in all Flowering Plants, the cells situated on the surface of the different organs which are exposed to the air, vary in form and in the nature of their contents from those placed beneath them, and are so arranged as to constitute a firm layer which may commonly be readily separated as a distinct membrane. To this layer the term *Epidermal Tissue* is given. It is generally described as consisting of two parts; namely, of an inner portion

called the *Epidermis*, and of an outer thin pellicle to which the name *Cuticle* has been given.

a. *Epidermis.*—This consists of one (*fig.* 66 *e*), two (*fig.* 83, *a*, *a*), three (*fig.* 84, *a*), or more layers of cells, firmly united together by their sides, and forming a continuous structure, except at the points where it is perforated by the stomata, presently to be described (*fig.* 88, *s*). These cells are generally of a flattene tabular character (*figs.* 83 and 84), the sides of which vary much in their outline; thus, in the epidermis of the *Iris* they are elongated hexagons (*fig.* 80, *e*, *e*); in that of the Maize they are zigzag (*fig.* 81, *b*, *b*); while in the garden Balsam they are very irregular or sinuous (*fig.* 82); and in the epidermis of other plants we find them square, rhomboid, &c.

FIG. 83.

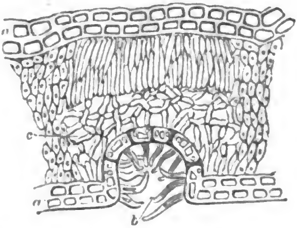


FIG. 84.

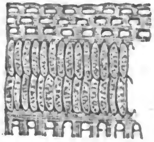


Fig. 83. Vertical section through the leaf of a Banksia. *a*, *a*. Epidermis with two rows of cells. *c*. Spongiform parenchyma. *b*. Hairs which are contained in little depressions on the under surface of the leaf. After Schleiden.——*Fig.* 84. Vertical section through the leaf of Oleander, showing the epidermis, *a*, composed of three layers of thick-sided cells, and placed above a compact parenchyma of vertical cells. After Brongniart.

The upper walls of the epidermal cells are generally much thickened and chemically altered or *cuticularised* as it is termed (*see* Cuticle), by which the cell-membrane is rendered impervious to moisture, and capable of protecting the more tender cells beneath from an undue loss of moisture from the scorching heat of the sun. This thickening of the upper walls of the epidermal cells may be especially observed in leaves of a leathery or hardened texture, as in those of the Oleander (*fig.* 84, *a*), and Hoya (*fig.* 86).

The cells of the epidermis are generally colourless, but in some cases they contain coloured fluids, and very rarely chlorophyll. The epidermis covers all the young parts of plants upon which it is found that are directly exposed to the air except the stigma, in Flowering Plants; and it is in all cases absent from those which live under water. No true epidermis is to be found in Thallophytes. The epidermis which at first covers the young branches of trees is replaced at a subsequent period by the corky layer of the bark.

FIG. 85.

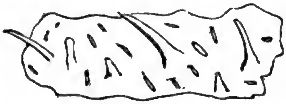


FIG. 86.

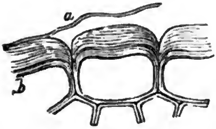
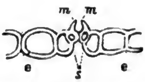


Fig. 85. Cuticle of the Cabbage, showing that it is perforated by the stomata, and forms sheaths over the hairs.——*Fig.* 86. Vertical section of the epidermis of *Hoya carnosa* treated with caustic potash. *a*. The detached cuticle. *b*. The thickened cuticularised layers of the outer walls of the epidermal cells. After Mohl.

b. *Cuticle.*—This generally consists of a thin transparent membrane, which covers the entire surface of the epidermal cells with the exception of the openings called stomata; it also forms a sheath over the hairs (*fig.* 85). The cuticle is formed on the outer walls of the cells which are exposed to the chemical influences of air and light. The cell-wall in such a position becomes greatly thickened and chemically altered in its texture; so much so that the outer part is clearly defined from the inner cuticularised layers, and can be stripped off as a distinct membrane or cuticle (*fig.* 86, *a*).

c. *Stomata.*—These are orifices situated between the sides of some of the epidermal cells, and opening into the intercellular spaces beneath, so as to allow a free communication between the internal tissues and the external air (*figs.* 87 and 88). These orifices are surrounded by cells with thinner walls and of a different form from those of the epidermis; they also usually contain some chlorophyll grains. There are generally but two cells surrounding the orifice, and these, which are usually termed *guard-cells*, are commonly of a more or less semilunar form (*fig.* 80, *s*), so that the whole has some faint resemblance to the lips and mouth of an animal, and hence the name of *stoma* applied to these structures, from στόμα, a mouth. In some cases we find four, or, very rarely, even more guard-cells. These guard-cells are either placed so as to be nearly or quite on a level with those of the epidermis, or when much increased in number, as in some of the Liverworts, they are arranged in tiers one above the other.

FIG. 87.



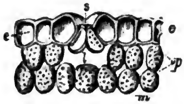


FIG. 88.

FIG. 89.

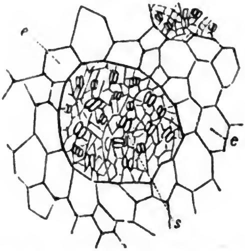


Fig. 87. Vertical section of the epidermis of *Leucadendron decorum*, showing *e*, *e*, the epidermal cells, with the stomatal cells, *s*, with elevated margins, *m*, *m*.——*Fig.* 88. Vertical section of the epidermis of the Iris. *s.* The stoma. *e*, *e*. Epidermis. *p*. Parenchyma beneath the epidermis. *l*. Intercellular space into which the stoma opens.——*Fig.* 89. Epidermis of the leaf of a species of *Saxifraga*, showing clustered stomata, *s*, with intervening spaces, *e*, *e*, in which they are absent.

The stomata vary in form and position in different plants, and in different parts of the same plant, but they are always the same in any particular part of a plant. The far more common form is the oval (*figs.* 80, *s*, *s*, and 81, *a*, *a*); but in some instances they are round, and in rare cases square. They are either placed singly upon the epidermis. at regular (*fig.* 80), or irregular intervals (*fig.* 82), or in clusters, the intervening epidermis having none (*fig.* 89); the former is the more common arrangement.

The number of stomata also varies considerably. Thus, from about 200 in one square inch of surface, as in the leaves of the Mistletoe, to nearly 160,000 in the same extent of surface, as in those of the Lilac.

Stomata are not found upon all plants. Thus they are absent from all Thallophytes, but in the higher orders of Cormophytes, as the Ferns and their allies, they abound, while in the Liverworts and Mosses they are confined to certain parts. They exist more or less upon all Flowering Plants and their organs. But they are far more abundant upon those which are green; thus they are found especially upon leaves, but more particularly on their under surface. On floating leaves, as in the Water-lily, however, we find them only on the upper surface. They occur also on the young green branches of plants and on the parts of the flower. In those plants which have no true leaves, as the Cactaceæ, they abound upon the green succulent stems. They are absent from roots and all submersed parts of plants; also from colourless parasites; and from the epidermis of plants growing in darkness so as to be blanched; and from the veins of leaves.

5. Appendages of the Epidermis.—Upon the surface of the epidermis, or in the sub-epidermal tissue, there are frequently to be found certain structures consisting of one or more cells of different forms, variously combined, and containing various substances. These are termed, collectively, *Appendages of the Epidermis*; and, as their name implies, they have no connexion with the fibro-vascular tissue of the leaves, stem, or branches. We shall treat of them under the two heads of *Hairs* and *Glands*.

(1.) *Hairs or Trichomes.*—These are thread-like prolongations externally of the epidermal cells covered by cuticle (*fig.* 85). They may either consist of a single cell, when they are called *simple hairs* (*figs.* 90–93), or of several cells, when they are termed *compound* (*figs.* 97 and 100). *Simple hairs*, again, may be undivided (*fig.* 90), or forked (*fig.* 91), or branched (*fig.* 92). A beautiful form of simple hair is that called stellate (*fig.* 93); that is formed by a cell dividing horizontally into a number of parts which are arranged in a star-like form.

FIG. 90.

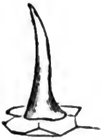


FIG. 91.

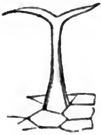


FIG. 92.

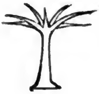


FIG. 93.

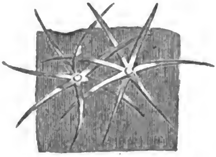


FIG. 94.

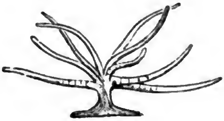


Fig. 90. Simple unbranched hair of the common Cabbage.——*Fig.* 91. Forked hair of Whitlow-grass (*Draba*).——*Fig.* 92. Branched stellate hair of *Alyssum.*——*Fig.* 93. Stellate hairs from *Althæa officinalis.*——*Fig.* 94. Branched hair of a species of *Marrubium.*

Compound hairs may be also undivided, as is more frequently the case (*fig.* 95), or branched (*fig.* 94). The component cells of compound hairs may be also variously arranged, and thus give a variety of forms to such hairs. Commonly their cells are placed end to end in a single row, so that the hairs assume a more or less cylindrical form; but when the component cells are contracted at the points where they come in contact, they become *moniliform* or *necklace-shaped* (*fig.* 95). When the cells below are larger than those above, so that the hairs gradually taper upwards to a point, they become *conical* ; or when gradually larger from the base to the apex, the hairs are *clavate* or *club-shaped* (*fig.* 96) ; or, when suddenly enlarged at their apex into a rounded head, *capitate* (*fig.* 97). When the cell at the end of a hair is terminated by a hook on one side pointing downwards, such hairs are called *uncinate* or *hooked* (*fig.* 98) ; or if there are two or more hooks at the apex, they are *glochidiate* or *barbed* (*fig.* 99). Hairs again, instead of being erect, or placed obliquely upon the epidermis, may develop horizontally in a more or less circular manner, and form *stellate hairs*, as in the Ivy (*fig.* 100) ; or two of the component

FIG. 95.

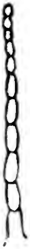


FIG. 96.

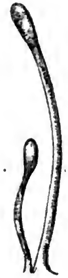


FIG. 97.

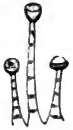
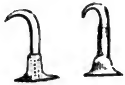


FIG. 98.



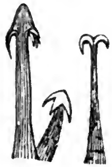


FIG. 99

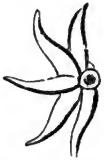


FIG. 100.

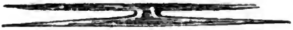


FIG. 101.

Fig. 95. Moniliform hair of the Virginian Spiderwort (*Tradescantia virginica*).——*Fig.* 96. Clavate hairs.——*Fig.* 97. Capitate hairs.——*Fig.* 98. Hooked hairs.——*Fig.* 99. Glochidiate or barbed hairs.——*Fig.* 100. Stellate hair from the Ivy.—— *Fig.* 101. Peltate hair from *Malpighia urens*.

cells may develop in opposite directions from another cell raised above the level of the epidermis, so as to produce what is termed a *shield-like* or *peltate hair* (*fig*. 101). Many hairs have one or more spiral fibres in their interior, as those on the outer coat of the fruit of *Salvia Horminum* (*fig*. 102).

FIG. 102.

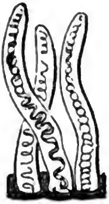


FIG. 103.

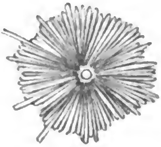


FIG. 104.

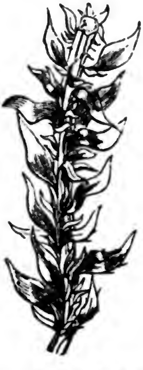


FIG. 105.

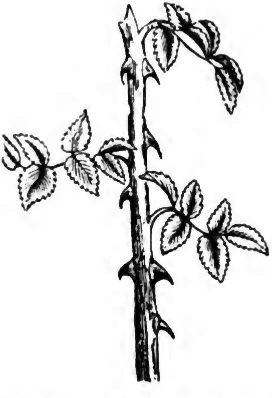


Fig. 102. Hairs, each with a spiral fibre in its interior, from the epicarp of the fruit of *Salvia Horminum*.——*Fig*. 103. Scale of Oleaster (*Elæagnus*).——*Fig*. 104. Ramenta from the petiole of a Fern.——*Fig*. 105. Prickles on a Rose-branch.

When the divisions of stellate hairs are closely connected by cuticle or otherwise, they form *scales* or *scurf* (*fig.* 103); such epidermal appendages are, therefore, simply modifications of stellate hairs.

Other modifications of hairs which are allied to the above, are the *ramenta* or *ramentaceous hairs* so frequently found upon the stem and petioles of Ferns. These consists of cells combined so as to form a brownish flattened scale attached by its base to the surface of the epidermis from whence it grows (*fig.* 104).

When the hairs are composed of cells which are short, and have their inner walls thickened so that they form stiffened processes, they are then called *setæ* or *bristles.* These, slightly modified, form *prickles*, which may be defined as large multicellular hairs which spring from the epidermis and layer of cells beneath, the walls of which are hardened by the deposition of lignin, and which terminate in a sharp point (*fig.* 105). They are especially abundant on the stems of the Rose and Bramble. Prickles and some other allied structures have been termed *Emergences.*

Hairs occur upon various parts of plants, and, according to their abundance and nature, they give varying appearances to their surfaces, all of which are distinguished in practical Botany by special names. The more common position of hairs is upon the leaves and young stems, but they are also found on the parts of the flower, the fruit, and the seed. On young roots we also find cells prolonged beyond the surface which are of the nature of hairs, and have therefore been termed *root-hairs* or *fibrils* (see Roots).

(2.) *Glands.*—This name is properly applied only to cells which secrete a peculiar matter, but it is also vaguely given to some other epidermal and subepidermal appendages. Glands may be conveniently arranged in two divisions according to their position, namely, *external* and *internal.*

a. *External Glands.*—These may be again divided into *stalked* and *sessile.* The *stalked glands* are either formed of a single cell, dilated at its apex by the peculiar fluid it secretes (*fig.* 106), or of two (*fig.* 110), or more (*fig.* 111) secreting cells, placed at the end of a hair; or they consist of a mass of secreting cells (*figs.* 108 and 109). The stalked glands are frequently termed *glandular hairs.*

FIG. 106. FIG. 107. FIG. 108. FIG. 109.

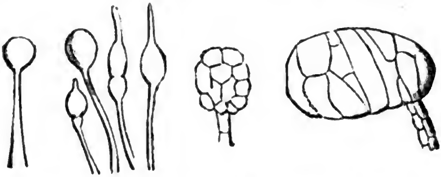


Fig. 106. Stalked unicellular gland of *Salvia.*——*Fig.* 107. Stalked unicellular glands of Snapdragon (*Antirrhinum majus*).——*Fig.* 108. Stalked many-celled gland of *Ailanthus glandulosa.*——*Fig.* 109. Stalked many-celled gland from *Begonia platanifolia.* From Meyen.

Sessile Glands present various appearances, and consist, like the former, of either one secreting cell, when they are commonly termed *papulæ* (*fig.* 113), or of two, or more (*fig.* 112).

FIG. 110. FIG. 111. FIG. 112. FIG. 113.

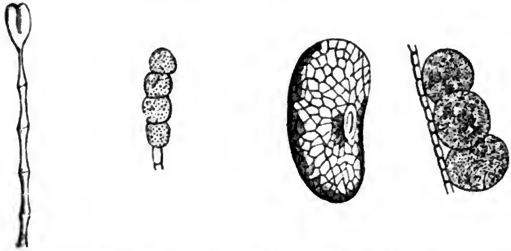


Fig 110. Stalked gland of Snapdragon, terminated at its summit by two secreting cells.——*Fig.* 111. Stalked gland with four secreting cells at its apex. From Meyen.——*Fig.* 112. Sessile many-celled gland from the common Hop (*Humulus Lupulus*).——*Fig.* 113. One-celled sessile glands, termed *papulæ* or *papillæ.*

When a sessile gland contains an irritating fluid and is elongated above into one or more hair-like processes, which are placed horizontally or vertically, we have a *sting* formed. In the Nettle (*fig.* 114), the sting consists of a single cell, enlarged at its base, *b*, by the irritating fluid, *f*, *f*, which it contains, and tapering upwards to near the apex, when it again expands into a rounded head, *s*. The enlarged base is closely invested by a dense layer of epidermal cells, *we*, which forms a kind of case to it.

FIG. 114.

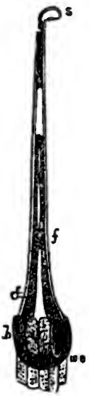


FIG. 115.

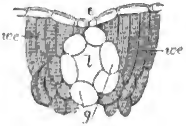


FIG. 116.

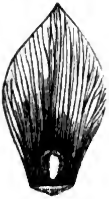


Fig. 114. Sting of the common Nettle (*Urtica dioica*), consisting of a single cell with a bulbous expansion at its base, *b*, and terminated above by swelling, *s*, and containing a granular irritating fluid, *f*, *f*. *we*. Epidermal cells surrounding its base.——*Fig.* 115. Internal gland from the leaf of the common Rue (*Ruta graveolens*). *g*. Gland surrounding a cavity, *l*, and itself surrounded by the epidermis, *e*, and the ordinary cells of the leaf, *we*. ——*Fig.* 116. Petal of Crown Imperial (*Fritillaria imperialis*), with a nectariferous gland at its base.

b. *Internal Glands.*—These are cavities containing secretions situated below the epidermis, and surrounded by a compact layer of secreting cells (*fig.* 115, *g*). In some cases they are of small size, as in the leaves of the Rue (*fig.* 115), Myrtle, and Orange. In those leaves they may be readily observed by holding them between the eye and the light, when they appear as little transparent spots; hence such leaves are termed *dotted*. This dotted appearance is due to the oily matters they contain refracting the light in a different manner to that of the other parts of the leaf. In other instances these glands are of large size, and project more or less beyond the surface in the form of little excrescences, as those in the rind of the Orange, Lemon, and Citron.

Holding a sort of intermediate position between the internal and external glands, are the true nectaries of flowers, which being strictly of a glandular nature will be most properly alluded to here under the name of *nectariferous glands*. They are well seen at the base of the petals of the species of *Ranunculus*, and in the Crown Imperial (*fig.* 116). These glands consist of a pore or depression into which a honey-like fluid or nectar is secreted, or rather excreted, by the surrounding cells.

6. INTERCELLULAR SYSTEM.—Having now described the different kinds of cells, and the modifications which they undergo when combined so as to form the tissues, we have in the next place to allude to certain cavities, which are placed between their walls, or produced by the destruction of some of their component cells. These constitute the *Intercellular System*.

a. *Intercellular Passages or Canals, and Intercellular Spaces.*—The cells being very commonly bounded by rounded surfaces, or by more or less irregular outlines, it must necessarily happen that when they come in contact with one another they can only touch at certain points, and therefore interspaces will be left between them, the size of which will vary, according to the greater or less roundness or irregularity of their surfaces. When such spaces exist as small angular canals running round the surfaces or edges of the cells and freely communicating with one another, as is especially evident in round or elliptical parenchyma (*fig.* 46), they are called *intercellular passages* or *canals*; but when they are of large size, as in spongiform tissue, they are termed *intercellular spaces* (*fig.* 65). In most cases these spaces and canals are filled with air, and when they occur in any organ exposed to the atmosphere which possesses stomata, they always communicate with them (*fig.* 88, *l*), by which means a free passage is kept up between the atmosphere and the air they themselves contain.

b. *Air Cavities.*—In water plants the intercellular spaces are commonly of large size, and bounded by a number of small cells regularly arranged by which they are prevented from communicating with each other, or with the external air (*fig.* 117); they are then commonly termed *air cavities.* In other instances we find large air cavities, as in the stems of Grasses and Umbelliferous plants, which have been formed by the destruction of their internal tissues by the more rapid growth of their outer portions; these large cavities have been termed *lacunæ.*

FIG. 117.

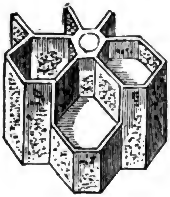


FIG. 118.

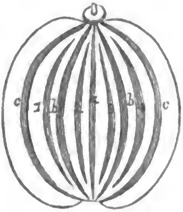


Fig. 117. Air cavities from the stem of *Limnocharis Plumieri.*——*Fig.* 118. Dorsal surface of the fruit of the Parsnip (*Pastinaca sativa*). *a*, *b*, *b*, *c*, *c*. Primary ridges. 1, 2, 3, 4. Vittæ. The vittæ are readily seen by noticing that they are shorter than, and alternate with, the ridges, *a*, *b*, *b*, *c*, *c*.

c. *Receptacles of Secretion.*—In many plants, again, the intercellular canals or spaces act as receptacles for the peculiar secretions of the plant; in which case they are termed *Receptacles of Secretion.* These receptacles vary much in form, but are usually more or less elongated. In the pericarp of the fruit of Umbelliferous plants they form the receptacles of oil, which have been termed *vittæ* (*fig.* 118, 1, 2, 3, 4).

d. *Intercellular Substance.*—The spaces above described as occurring between the walls of adjoining cells appear in some few cases to be filled up by solid matter, to which the name of *intercellular substance* has been given. This intercellular substance was supposed to be universally distributed between the cells, and in some plants in great abundance, as in many Algæ, the horny albumen of seeds, and in the collenchymatous cells of the Begonia (*fig.* 66, *cl*, *cl*), &c. But in all these cases this appearance is due to alterations and changes which have taken place in the cellulose forming the cell-wall and contents of the cell.

CHAPTER III.

ORGANS OF NUTRITION.

HAVING now considered the elementary structures of plants, we proceed to describe in detail the various compound organs which they form by their combination. These, as already noticed (page 14), are arranged in two divisions, namely: 1. *Organs of Nutrition*, and 2. *Organs of Reproduction.* We commence with the organs of nutrition, and shall first describe the stem, or *caulome*, as it is now frequently termed.

Section 1. THE STEM OR CAULOME.

THE stem may be defined as that part of the axis which at its first development in the embryo takes an opposite direction to the root, seeking the light and air, and hence termed the ascending axis, and bearing on its surface leaves and other leafy appendages. This definition will, in numerous instances, only strictly apply to a stem at its earliest development, for it frequently happens that, soon after its appearance, instead of continuing to take an upward direction into the air, it will grow along the ground, or even bury itself beneath the surface, and thus by withdrawing itself from the light and air it resembles, in such respects, the root, with which organ such stems are, therefore, ordinarily confounded. In these cases, however, a stem is at once distinguished from a root by bearing modified leaves, each of which has also the power of forming a leaf-bud in its axil. The presence of leaves and leaf-buds is therefore the essential characteristic of a stem, in contradistinction to a root, in which such structures are always absent. Those plants in which the stem is clearly evident are called *caulescent*, while those in which it is very short or inconspicuous are termed *acaulescent* or *stemless*.

1. INTERNAL STRUCTURE OF THE STEM IN GENERAL.—A stem in its simplest condition consists merely of parenchyma with a central vertical cord of slightly elongated, somewhat thickened cells. Examples of such a stem may be commonly seen in Mosses (*fig.* 8). Such a structure, however, would be unsuited to plants except those of low organisation, and we accordingly find, as a rule, that in all plants above the Mosses the stem is made up partly of parenchyma, and partly of woody tissue and vessels of different kinds, by which the requisite strength and toughness are produced. In such stems therefore we distinguish two systems, namely, a *Parenchymatous* or *Cellular*, and a *Fibro-vascular*. The *parenchymatous system* grows in any direction according to circumstances, either longitudinally, by which the stem is lengthened, or horizontally, by which it is increased in diameter. The *fibro-vascular system*

only grows longitudinally, and thus forms cords or bundles which are distributed vertically in the midst of the parenchymatous. The *parenchymatous system* is therefore also termed the *horizontal system*, while the *fibro-vascular* is likewise called the *longitudinal system.*

In their internal structure the stems of plants are subject to numerous modifications, all of which may be, however, in their essential particulars, reduced to three great divisions, two of which are found in Phanerogamous Plants, and one in Cryptogamous; hence such Cryptogamous Plants are distinguished under the name of Cormophytes. As illustrations of the two former we may take an Oak and a Palm stem; of the latter, that of a Tree-fern.

FIG. 119.

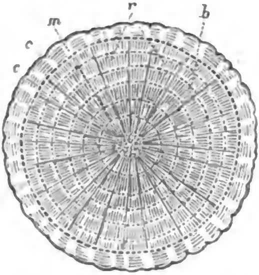


FIG. 120.

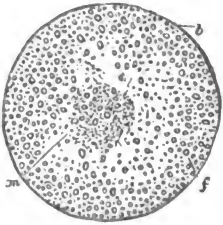


Fig. 119. Transverse section of an Oak-branch six years old. *m.* The medulla or pith. *c. c.* The bark. *r.* The wood. *b.* Medullary rays.——*Fig.* 120. Transverse section of the stem of a Palm. *m.* Parenchyma. *f.* The fibro-vascular bundles. *b.* The rind or false bark.

Upon making a transverse section of an Oak (*fig.* 119), we observe that the two systems of which the stem is composed are so arranged as to exhibit a distinct separation of parts. Thus we have a central one, *m*, called the *pith*; an external one, *c c*, or *bark*; an intermediate *wood*, *r*, arranged in concentric layers, known as the annual rings; and little rays, *b*, connecting the pith and the bark, termed *medullary rays*. Such a stem grows essentially in diameter by the annual additions of a new ring of wood on the outside of the previous wood, and hence it is called Exogenous (from two Greek words signifying *outside growers*).

In a Palm stem no such distinction of parts can be noticed (*fig.* 120), but upon making a transverse section we observe a mass of parenchyma, *m*, more or less distributed throughout it, and the fibro-vascular system

FIG. 121.

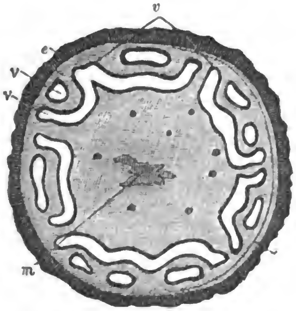


Fig. 121. **Transverse section of the stem of a Tree-fern. *m*. Parenchyma, which is wanting in the centre. *v*, *v*, *v*. Fibro-vascular bundles. *e*. Rind.**

arranged vertically in this in the form of separate bundles, *f*, which have no tendency to form concentric layers of wood; the whole being covered externally by a fibrous and parenchymatous layer, *b*, which is termed the *false bark* or *rind*. This structure is called Endogenous (from two Greek words signifying *inside growers*), as such stems grow by the addition of new fibro-vascular bundles which are at first directed towards their interior.

If we now make a transverse section of a Tree-fern (*fig.* 121), we observe the centre, *m*, to be either hollow or filled with parenchyma, the fibro-vascular bundles being arranged in irregular sinuous plates, *v*, *v*, *v*, around it and forming a continuous or interrupted circle near the circumference, which consists of a rind, *e*, inseparable from the wood beneath. This structure is termed Acrogenous (from two Greek words signifying *summit growers*), because such a stem grows only by additions to its apex.

The characteristic peculiarities thus found to exist in the internal appearances and growth of these three kinds of stem are due to corresponding differences in their component parts, or, as they are commonly called, their *fibro-vascular bundles*. Thus the *fibro-vascular bundle* of an Exogenous stem (*fig.* 122) consists in the first year of growth of a layer of spiral vessels, *s*, *v*, surrounding the pith, *p*; and on the outside of this layer there are subsequently developed, in perennial plants, pitted vessels, *d*, and wood-cells, *w*, which together form the wood. But in herbaceous plants annular and reticulated vessels are also found intermixed with the wood-cells. The wood is covered externally by a layer of vitally active or generating cells, *c*, called the *cambium* (see page 82), on the outside of which are the liber, *l*, the cellular parts of the bark, *ce*, and the epidermis, *e*. The different kinds of tissue which are placed between the cambium layer and the pith form what has been called the *xylem* or *woody portion* of the bundle; and those outside forming the liber—that portion which has been termed the *phloëm*; so that the fibro-vascular bundle has the pith, *p*, on its inner surface and is covered externally by the cellular layers, *ce*, of the bark. In these bundles the growth of the different parts is *progressive*, the inner part of each being first formed, and growth gradually proceeding to the outside, and as they always contain a cambium layer they are capable of further growth, and thus form periodically new layers of xylem and phloëm, and are therefore called *indefinite* or *open fibro-vascular bundles*.

It also necessarily follows from the cambium layer being placed between the xylem and the phloëm, that the layers of increase to these parts of the bundle are in continuity with the previous layers.

In Endogenous stems the *fibro-vascular bundles* (*fig.* 123) consist internally of wood-cells, *w*, and spiral vessels, *s v*; on the outside of which other spiral vessels are formed, as well as pitted, *d*, and other vessels; these are succeeded by a number of delicate parenchymatous cells, *c*, corresponding to cambium cells, which are gradually converted into thick-sided prosenchymatous cells, *l*, resembling those of the liber of

FIG. 122.

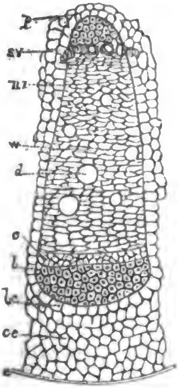


FIG. 123.

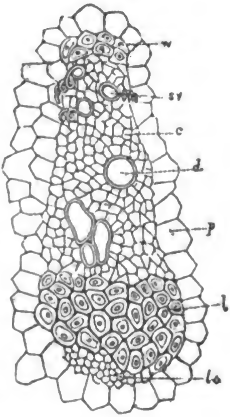


Fig. 122. Transverse section of a fibro-vascular bundle of an Exogenous stem. *p.* Pith. *sv.* Spiral vessels. *mr.* Medullary ray. *w.* Wood-cells. *d.* Pitted vessels. *c.* Cambium layer. *l.* Liber or phloëm. *lc.* Laticiferous vessels. *ce.* Cellular portion of the bark. *e.* Epidermal tissue.——*Fig.* 123. Transverse section of a fibro-vascular bundle of an Endogenous stem (Palm), the upper portion being directed to the centre. *w.* Wood-cells. *sv.* Spiral vessels. *c.* Cambium-cells. *d.* Pitted vessels. *p.* Parenchyma surrounding the bundle. *l.* Liber-cells. *lc.* Laticiferous vessels.

Exogenous stems. On the outside of these liber-cells are some laticiferous vessels, *lc*; and the whole bundle is surrounded by parenchyma, *p*. In this case the development of the fibro-vascular bundles, like those of Exogenous stems, is gradual, the inner part of each being first formed and growth proceeding progressively to the outside; hence these also are progressive bundles; but, as such bundles have no layer of generating cells resembling the cambium layer, no increase in size can take place in them in successive seasons, as in the indefinite fibro-vascular bundles of Exogenous stems. Hence the new bundles are not developed in continuity with the old, but remain distinct and of limited size. They are therefore named *definite* or *closed fibro-vascular bundles.*

In Acrogenous stems the *fibro-vascular bundles* are chiefly made up of vessels of the scalariform, annular, or spiral type, according to the plants in the different orders of Cormophytes to which they belong; these are surrounded by delicate tubular cells, and the whole is enclosed by a firm layer of that variety of parenchyma known as sclerenchyma. Such bundles only grow by additions to their summit, and as the elements of which they are composed are not formed in succession like those of indefinite and definite fibro-vascular bundles, but simultaneously, they have been called *simultaneous fibro-vascular bundles*; and as these bundles, like those of Endogenous stems, have no layer of cambium cells, they are also said to be closed.

The plants which present these distinctive appearances and modes of growth in their stems have also certain differences in the structure of their embryo. Thus plants with Exogenous stems have an embryo with two cotyledons; those with Endogenous stems have but one cotyledon in their embryo; while those with Acrogenous stems have no proper embryo, and consequently have no cotyledons. Hence Exogenous stems are also termed *Dicotyledonous*; Endogenous stems *Monocotyledonous*; and Acrogenous stems *Acotyledonous.* With these general remarks on the internal structure of the three kinds of stems we now proceed to describe them respectively in detail.

A. EXOGENOUS OR DICOTYLEDONOUS STEM.—All the trees and large shrubs of this country, and with rare exceptions those of temperate and cold climates, are exogenous in their growth. In warm and tropical regions such plants occur associated with those possessing endogenous and acrogenous structure; but Dicotyledonous plants are far more abundant even in those parts of the earth.

In the embryo state, the Exogenous stem is entirely composed of parenchyma; but at the end of the first year's growth the stem presents the following parts (*fig.* 124): 1. A central mass of parenchyma, *m*, which is called the *Medulla* or *Pith*; 2. An interrupted ring of spiral vessels, *t*, called the *Medullary sheath*; 3. An interrupted zone or ring of wood-cells and vessels, forming the *Wood*; 4. A layer of very delicate thin-walled cells, the *Cambium layer*; 5. Radiating lines, *r*, connecting the pith with the cambium layer and bark, the *Medullary rays*; and 6. The *Bark*, *b*, a mass of parenchyma surrounding the whole stem, and containing in its interior liber-cells, &c., and invested on its external surface by the *Epidermis*.

FIG. 124.

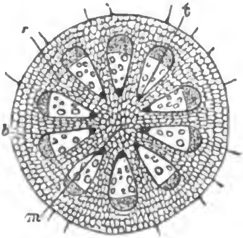


Fig. 124. Horizontal section of the first year's stem or branch of an Exogenous stem. *m.* Pith. *r.* Medullary rays. *t.* Spiral vessels forming the medullary sheath, on the outside of which are the other elements of the fibro-vascular bundle. *b.* Bark.

Each succeeding year's growth is essentially a repetition of that of the first year, except as regards the pith and spiral vessels; the former of which does not increase in size after the first year, and the latter are never repeated, so that in old stems we have no more distinct regions than in those of the first year. We have consequently in all Exogenous stems the following parts,—namely, *pith*, *medullary sheath*, *wood*, *medullary rays*, *cambium layer*, and *bark*—which we shall now describe in the order in which they are placed.

(1) *Pith or Medulla* (*figs.* 124, *m*, and 125, B, *a*, *a*).—This consists essentially of parenchyma, and it forms a more or less cylindrical or angular column which is situated commonly at, or towards, the centre of the stem. As a general rule the pith is not continued into the root, but it is always in connexion with the terminal bud of the stem, and also at first indirectly by the medullary rays with all the lateral leaf-buds; as the latter, however, continue to develop, their connexion with the central pith is cut off, as will be explained hereafter in speaking of their structure and origin. The parenchyma of which the pith is composed is generally that kind which is known as *regular* (*fig.* 48), so that when a section is made of it, and examined microscopically, it presents an hexagonal (*fig.* 125, B, *a*, *a*), or polyhedral appearance.

In the earliest stages of the plant's existence the whole of it consists of parenchyma; and out of this tissue, by the differentiation of special cells, the more elaborate spiral and other vessels, and wood-cells, are developed. As, however, these elements of the fibro-vascular bundles increase in number, they encroach upon the parenchyma, and thus circumscribing the central portion till it assumes the appearance of a continuous column or pith (*fig.* 124, *m*), filling the interior of the stem, and giving off the medullary rays, *r*, as flattened plate-like processes, which connect the pith with the cellular layers of the bark, *b*. That portion of the parenchyma which thus remains is called the *fundamental tissue.*

Instead of continuing to form an uninterrupted column, the pith, in after years, owing to the external parts growing rapidly, becomes more or less broken up; and even in many herbaceous plants, such as the Hemlock and others, which grow with great rapidity, it is almost entirely destroyed at an early period of the plant's life, and large air cavities are formed in the interior of the stem.

The diameter of the pith varies much in different plants, and also in different branches of the same plant. It is generally very small in hard-wooded plants, as in the Ebony and Guaiacum; while in soft-wooded plants, as the Elder and Ricepaper Plant (*Tetrapanax* (*Aralia*) *papyrifera*), it is of large size.

(2) *The Medullary Sheath* (*fig.* 125, B, *d*) consists of spiral vessels which are situated on the innermost part of the ring of wood which forms the first year's growth. They do not form a continuous sheath to the pith (*fig.* 124, *t*), but spaces are left between them, through which the medullary rays, *r*, pass outwards. As the spiral vessels are never repeated after the first year's growth, the medullary sheath is consequently the only part of the stem in which they normally occur.

(3) *The Wood or Xylem.*—This is situated between the pith on its inside and the bark on its outer (*fig.* 119, *r*), and it is separated into wedge-shaped bundles by the passage through it of the medullary rays, *b*. In the first year's growth of an exogenous stem the wood is deposited in the form of an interrupted ring immediately surrounding the pith (*fig.* 124, *t*); and that portion which is first developed consists, as just noticed, of spiral vessels (*figs.* 124, *t*; and 125, B, *d*), which form the *medullary sheath.*

On the outside of the medullary sheath, the ring of wood forming the first year's growth (*fig.* 125, B, 1) consists of woody tissue, *c*, among which are distributed, more or less abundantly, some vessels, *b*, chiefly of the kind called pitted in perennial plants; although in herbaceous plants we have also annular and other vessels.

When the stem lasts more than one year a second ring of wood is formed from the cells of the cambium layer which are placed on the outside of the first ring. This second ring (*fig.* 125, B, 2) resembles in every respect that of the first year, except that no medullary sheath is formed; it consists therefore entirely of woody tissue and pitted vessels, *c*, *b*. In the third year of growth another ring of wood is produced precisely resembling the second (*fig.* 125, 3), and the same is the case with each succeeding annual ring as long as the plant continues to live. It is in consequence of each succeeding layer of wood being thus deposited on the outside of those of the previous years, that these stems

FIG. 125.

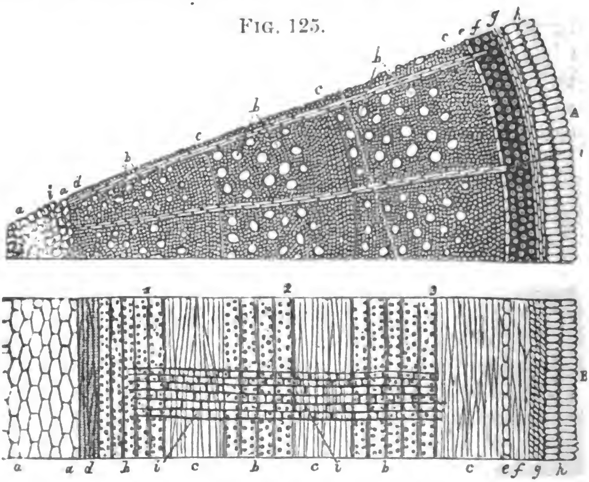


Fig. 125. Diagram showing the structure of an Exogenous stem three years old. A. Horizontal section. B Vertical section. The figures 1, 2, 3, refer to the years of growth of the wood, and the letters mark similar parts in both sections. *a*, *a*. Pith. *d*. Spiral vessels. *b*, *b*. *b*. Pitted vessels. *c*, *c*, *c*. Wood-cells. *e*. Cambium layer. *f*. Inner layer of bark or liber (*phloëm*). *g*. Middle layer of bark. *h*. Outer layer of bark. *i*, *i*. Medullary rays. After Carpenter.

are called *exogenous.* In the stems of Gymnospermous plants, as those of the Fir, the annual rings of wood, which are well marked, instead of being formed of ordinary woody tissue, and pitted vessels, consist essentially of wood-cells with bordered pits. Hence upon making a transverse section of the wood of such trees, the openings will be observed to be nearly of the same size; while in the transverse section of the wood of other exogenous trees the pitted vessels may be at once distinguished from the wood-cells by the larger size of their openings (*fig.* 125, A, *b*, *b*, *b*).

The pitted vessels in ordinary trees are also commonly more abundant on the inner part of each annual ring, the wood-cells forming a compact layer on the outside (*fig.* 125, A, *c*, *c*, *c*). In such cases the limits of each ring are accurately defined. In those trees which have the pitted vessels more or less diffused throughout the woody tissue, as in the Lime and Maple, the rings are by no means so evident, and can then only be distinguished by the smaller size of the wood-cells on the outside of each layer, which appearance is caused by their diminished growth towards the end of the season.

When the annual layers are first formed, the walls of their component wood-cells and vessels are pervious to fluids, and very thin, and their cavities gorged with *sap.* But as they increase in age, their walls become so thickened that their cavities are ultimately almost or entirely obliterated, and they are then impervious to fluids. This change is especially evident in the wood of those trees in which the thickening layers are of a coloured nature, as in the Ebony and Guaiacum. Such coloured portions are generally most evident in tropical trees, although they also occur more or less in most of the trees of cold and temperate regions. In some of the latter, however, as the Poplar and the Willow, the whole of the wood is nearly colourless, and exhibits but little difference in the appearance of the internal and external layers.

From the above characters presented by the wood according to its age, we distinguish in it two parts: namely, an internal portion, in which the wood-cells and vessels have thickened walls, are impervious to fluids, hard in texture, of a dry nature, and commonly more or less coloured, which is called the *Duramen*, or *Heart-wood*; and an outer portion in which the wood-cells and vessels have thin sides, are pervious to, and full of sap, soft in texture, and pale or colourless, to which the name of *Alburnum* or *Sap-wood* is given.

Age of Dicotyledonous Trees.—As each ring of wood in an Exogenous stem is produced annually, it should follow that by counting the number of rings in a transverse section of the stem of such a tree, we ought to be able to ascertain its age This is true with a few exceptions, when such trees are natives of cold climates, because in these the annual rings are usually distinctly marked; but in Dicotyledonous trees of warm climates it is generally difficult, and frequently impossible, to ascertain their age in this manner, in consequence of several disturbing causes: thus, in the first place, the rings are by no means so well defined; secondly, more than one ring may be formed in a year; thirdly, some trees, such as *Zamias*, only produce one ring as the growth of several years; fourthly, some plants, as certain species of *Cacti*, never form annual rings, but the wood, whatever its age, only appears as a uniform mass; while, lastly, in some trees, such as *Guaiacum*, the rings are not only indistinct, but very irregular in their growth.

It is commonly stated that the age of a tree may not only be ascertained by counting the annual rings in a transverse section of the wood, but that the mere inspection of a fragment of the wood of a tree of which the diameter is known, will also afford data by which the age may be ascertained. The manner of proceeding in such a case is as follows:—Divide half the diameter of the tree divested of its bark by the diameter of the fragment, and then, having ascertained the number of rings in that fragment, multiply this number by the quotient previously obtained. Thus, suppose the diameter of the fragment to be two inches, and that of half the diameter of the wood twenty inches; then, if there are eight rings in the fragment, by multiplying this number by ten, the quotient resulting from the division of half the diameter of the tree by that of the fragment, we shall get eighty years as the supposed age. Now, if the thickness of the rings was the same on both sides of the tree, and the pith consequently central, such a result would be perfectly accurate, but it happens from various causes that the rings are frequently much thicker on one side than on the other, and a fragment taken therefore from either side indifferently would lead to very varying results. A better way to calculate the age of a tree by the inspection of a fragment is to remove two pieces from its two opposite sides, and then, having ascertained the number of rings in each, take the mean of that number, and proceed as in the former case. Thus, suppose two inches, as before, removed from the two opposite sides of a tree, and that in one we have eight rings, and in the other twelve, we have ten rings as the mean of the two. If we now divide, as before, half the diameter, twenty inches, by two, and multiply the quotient ten which results, by ten, the mean of the number of rings in the two notches, we get one hundred years as the age of the plant under consideration. Such a rule in many cases will no doubt furnish a result tolerably correct, but even this will frequently lead to error, from the varying thickness of the annual rings produced by a tree at different periods of its age.

It is probable that, from not sufficiently taking into account the variations in the growth of the annual rings at different periods of their age, and their varying thickness on the two sides of the tree, the ages of such trees have been sometimes over-estimated. But still there can be no doubt that Dicotyledonous trees do live to a great age; in fact, when we consider that the new rings of wood are developed from the cambium cells which are placed on the outside of the previous rings, and that it is in these new annual rings that all the active functions of the plant are carried on, there can be, under ordinary circumstances, no direct limit to their age.

Size of Dicotyledonous Trees.—As there is no assignable limit to the age of Dicotyledonous trees in consequence of their mode of growth, so in like manner the same circumstance leads, in many cases, to their attaining a great size. Thus the *Sequoia gigantea* has been measured 116 feet in circumference at the base; and even Oaks in this country have been known to measure more than 50 feet in circumference; and many other remarkable examples might be given of such trees attaining to an enormous size, which circumstance is of itself also an evidence of their great age.

(4) *Cambium-layer or Cambium* (*fig.* 125, A and B, *e*).—On the outside of each annual ring of wood, as we have already seen, a layer of vitally active cells is placed, to which the name of *cambium-layer* or *cambium* has been given. It is from these cambium cells that new layers of wood and phloëm are annually formed, and from the cambium-layer being situated between the xylem and the phloëm of the indefinite fibro-vascular bundles of which Exogenous stems are composed, it follows that the layers of increase to these parts of the bundle are in continuity with the previous layers. The cells composing the cambium-layer are of a very delicate nature, and consist of a thin wall of cellulose, containing a nucleus, protoplasm, and watery cell-sap; in fact, all the substances which are present in young growing cells. The cambium-layer is called a generating tissue or *meristem*, because its cells are capable of dividing and forming *permanent tissue*. or that in which the cells have ceased to divide, but have assumed their definite form.

(5) *Medullary Rays.*—We have already seen that at first the stem consists entirely of parenchyma, but at the end of the first year's growth, in consequence of the development of the wood and phloëm, this parenchyma becomes separated into two regions—an internal or pith, and an external forming the cellular layers of the bark; the separation however not being complete, but the two being connected by tissue of the same nature as themselves, to which the name of *medullary rays* has been applied (*fig.* 119, *b*, and 124, *r*).

The cells forming these medullary rays, like those of the pith, are part of the fundamental tissue of the stem (page 76); but they differ from them in form, and become much flattened (*fig.* 50) in a radial direction, owing to the pressure which the neighbouring wedges of the fibro-vascular bundles have exerted upon them. As new rings of wood are formed in successive years, fresh additions are made to the ends of the medullary rays from the cambium, so that, however large the space between the pith and the cellular portion of the bark ultimately becomes, the two are always kept in connexion by their means. Besides the medullary rays, which thus extend throughout the entire thickness of the wood, others are also commonly developed between them in each succeeding year, which extend from the rings of those years respectively to the bark; these are called *secondary medullary rays.*

The medullary rays are composed of flattened six-sided cells, which are placed one above the other in one or more rows, like the bricks in a wall, hence the tissue which they form is termed *muriform parenchyma* (*figs.* 125, B, *i*, *i*; and 50). The tissue formed by the medullary rays is not continuous from one end of the stem to the other, but the rays are more or less interrupted by the passage between them of the fibro-vascular tissue forming the wood, so that they are split up vertically into a number of distinct portions (*fig.* 126, *rm*). This arrangement may be best observed by making thin sections of the wood perpendicular to the rays—that is, tangential to the circumference of the stem. The medullary rays constitute the *silver grain* of cabinet-makers and carpenters.

(6) *The Bark or Cortex.*—The bark is situated on the outside of the stem, surrounding the wood (*fig.* 119, *c. c*), to which it is organically connected by means of the medullary rays and cambium-layer. When the stem is first formed the bark is entirely composed, like the pith, of parenchyma, but as soon as the wood begins to be developed on the outside of the pith, certain cells which lie nearer the surface of the stem make their appearance, which develop into liber-cells (*fig.* 127, *d*). Externally to these lie other parenchymatous cells, the inner ones of which form the green layer of the bark, *c*, whilst the outer cells become de-

FIG. 126.

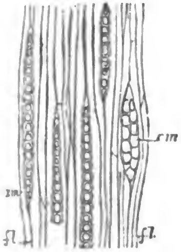


FIG. 127.

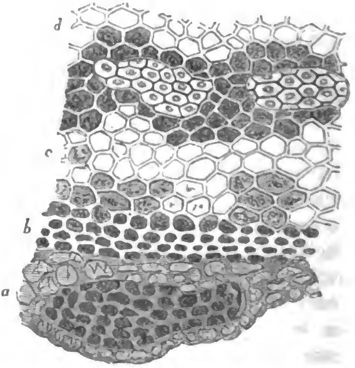


Fig. 126. Vertical section of a branch of the common Maple, perpendicular to the medullary rays. *fl, fl.* Fibro-vascular tissue forming the wood. *rm, rm.* Medullary rays.——*Fig.* 127. Transverse section of a portion of the bark of an Exogenous stem. *a.* Epidermis. *b.* Corky layer. *c.* Cellular envelope. *d.* Liber or Phloëm.

veloped into the cork tissue, *b*, and these again are invested by colourless cells, forming the epidermis, *a*, so that the bark, when fully formed, consists of two distinct systems: namely, an *internal* or *fibro-vascular*, and an *external* or *parenchymatous*. Further, the parenchymatous system, as just noticed, exhibits a separation into two portions; so that the fully developed bark accordingly presents three distinct layers, in addition to the epidermis, which is common to it and the other young external parts of plants. The three layers proper to the bark are called, proceeding from within outwards: 1. *Liber*, *Inner Bark*, or *Phloëm* (*figs.* 127, *d*, and 125, A and B, *f*, *f*); 2. *Cellular Envelope*, *Green Layer*, or *Phelloderm* (*figs.* 127, *c*, and 125, *g*, *g*); and 3. *Corky Layer*, *Outer Bark*, or *Periderm* (*figs.* 127, *b*, and 125, *h*, *h*).

a. *The Liber*, *Inner Bark*, *or Phloëm* (*figs.* 127, *d*, and 125, A and B, *f*, *f*).—This is composed of true bast tissue, or, as it is also called, woody tissue of the liber, and consisting of narrow elongated cells with thickened and flexible walls, mixed with parenchymatous tissue, and usually laticiferous vessels and sieve-tubes. The phloëm, therefore, belongs to the fibro-vascular system. The liber-cells of which it is essentially composed are either placed so as to form by their union a continuous layer; or, far more frequently, they present a wavy outline, so that numerous interspaces are left between their sides. From this circumstance the inner bark when macerated in water commonly presents a netted appearance.

b. *The Cellular Envelope*, *Green Layer*, *or Phelloderm* (*figs.* 127, *c*, and 125, A and B, *g*, *g*).—This, the middle layer of the bark, consists essentially of thin-sided, usually angular or prismatic, parenchymatous cells (*fig.* 127, *c*); which are loosely connected, and thus leave between their walls a number of interspaces. The cells of which it is composed contain an abundance of chlorophyll, which gives the green colour to young bark, and hence the name of *green layer*, by which it is also commonly distinguished. It is also sometimes known under the name of *phelloderma*. This layer and the next belong to the fundamental tissue, and form together the parenchymatous system of the bark.

c. *Corky Layer, or Periderm* (*figs.* 127, *b*, and 125, A and B, *h*, *h*).—This is the outer layer of the bark, and is invested by the epidermis (*fig.* 127, *a*). It consists of one or more layers of tabular cells generally elongated more or less in a horizontal direction, and which in most cases ultimately become dried up and filled with air, and forming by their union a compact tissue, or one without interspaces. It is this layer which gives to the young bark of trees and shrubs their peculiar hues, which are generally brownish or some colour approaching to this; or rarely it possesses more vivid tints. In some plants, as in the Cork-oak, this layer becomes excessively developed and forms the substance called *cork*, and hence the name *corky layer* which is commonly applied to it.

On the young bark of most plants may be observed little circular brownish or whitish specks, which have been called *lenticels* (*fig.* 128, *l*, *l*). They are formed of loosely aggregated cork-cells, separated by intercellular spaces, and, like stomata, specially designed to admit air to the living cortical tissue beneath.

FIG. 128.

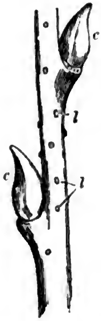


Fig. 128. Branch of a species of Willow. *l*, *l*. Lenticels. *c*, *c*. Buds.

Growth of the Bark.—The bark, except the middle layer, developes in an opposite direction to that of the wood, for while the latter increases by additions to its outer surface, the former increases by additions to its inner. The bark is therefore essentially endogenous in its growth; while the wood is exogenous. Each layer of the bark also grows separately; thus the liber by the addition of new matter from the cambium-layer on its inside; and the phelloderm and periderm from a special meristem, which is termed the *cork cambium* or *phellogen.* This phellogen is placed between the phelloderm and the periderm, so that it developes cork-cells on its outside, and the cells of the phelloderm on its inner surface. The two outer layers generally cease growing after a few years, and become dead structures on the surface of the tree; but the inner bark continues to grow throughout the life of the individual, by the addition of a new layer annually on its inner surface from the cambium. These layers are commonly so thin when separated that they appear like the leaves of a book, and hence the supposed origin of the term *liber* applied to the inner bark; but the name may have been derived from the inner bark having been formerly used for writing upon. In some trees, as in the Oak, these layers may be readily observed up to a certain age; but this distinction of the liber into layers is generally soon lost, in consequence of the pressure to which it is subjected from the growth of the wood beneath.

The outer layers of the bark, after a certain period in their life, which varies in different plants, generally become cracked in various directions in consequence of the pressure which is exerted upon them by the growth of the wood and liber beneath, and thus assume a rugged appearance, as in the Elm and Cork-oak. When the bark has thus become cracked and rugged, it is commonly thrown off in large pieces, or in plates or layers of various sizes and appearances. The epidermis in all cases separates early and is replaced by cork-cells. By this exfoliation and peeling off of portions of the bark, its thickness is continually diminished. This decaying and falling away of the outer layers in the old bark does not in any way injure the tree; hence it is evident that the old layers of the bark, like the pith and inner layers of the wood, have nothing to do with its life and growth after a certain period. The new layers of wood, the cambium-layer, and the recently formed liber, are the parts of an exogenous stem which are alone concerned in its active development and life.

B. ENDOGENOUS OR MONOCOTYLEDONOUS STEM.—In this country we have no indigenous trees or large shrubs which exhibit this mode of growth, although we have numerous herbaceous plants, such as Grasses, Rushes, and Sedges, which are illustrations of endogenous structure. But it is in the warmer regions of the earth, and especially in the tropics, where we find the most striking and characteristic illustrations of such stems, and of all such the Palms are by far the most remarkable.

When we make a transverse section of a Palm stem, it presents, as we have seen (page 71), no such separation of parts into pith, wood, medullary rays, and bark, as we have described as existing in an Exogenous stem; but the fibro-vascular system is seen to consist of bundles (*figs.* 120, *f*, and 129, A, *b*, *c*, *d*), which have no tendency to collect together and form rings of wood as in Exogenous stems, but are arranged separately from one another in the mass of parenchymatous cells (*figs.* 120, *m*, and 130, A, *a*), of which the fundamental tissue is composed. The whole is covered externally by a fibrous and parenchymatous layer, which is called the *false bark* or *rind* (*fig.* 120, *b*); because this is not a distinct and parallel formation to the wood, as is the case with the bark of Exogenous stems, but is formed essentially by the ends of the fibro-vascular bundles, as will be presently noticed, and cannot therefore be separated from the mass beneath.

In annual or herbaceous Endogenous stems the parenchyma between the fibro-vascular bundles is soft and delicate, but in trees which grow to any height, as Palms, the cell-walls become thickened and hardened, and thus form the tissue termed *sclerenchyma*, which ultimately binds the bundles into a solid hardened mass resembling wood.

Origin and Growth of the Fibro-Vascular Bundles. —The structure of the fibro-vascular bundles thus distributed in the parenchymatous system has been already

FIG. 129.

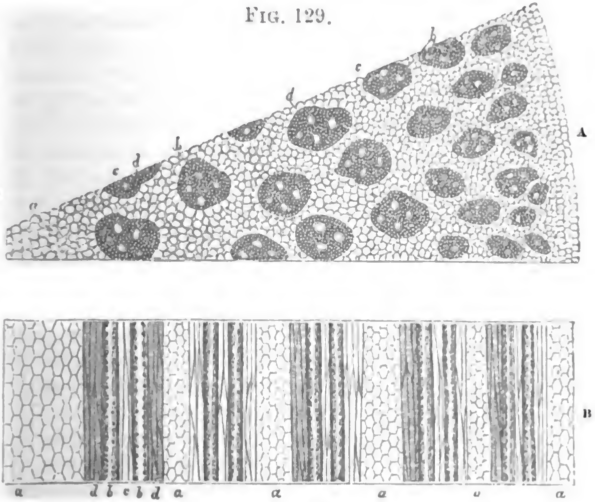


Fig. 129. Diagram of a Monocotyledonous stem. A. Transverse section. B. Vertical section. *a, a.* Parenchymatous tissue. *b, b.* Pitted vessels. *c.* Wood-cells. *d, d.* Spiral vessels. After Carpenter.

referred to under the name of *definite* or *closed* (page 73); but we have still to describe their origin and direction through the stem. These bundles have their origin in the *punctum vegetationis* of the stem, and are fully developed with its growth upwards and outwards into the leaves, and downwards and outwards towards the circumference of the stem. In other words, the bundles may be traced to the leaves, from which organs they are at first directed towards the interior of the stem (*fig.* 130, *a*, *b*, *c*, *d*), along which they descend generally for some distance, and then gradually curve outwards again and terminate at the circumference. Hence when we make a vertical section of an Endogenous stem, these bundles are seen to intersect one another in various ways.

The fibro-vascular bundles in their course down the stem also become altered in their structure. Thus when they first originate they consist, as we have seen (page 73), of spiral, pitted, and other vessels, mixed with parenchymatous and woody tissues (*fig.* 130, B, *b*, *b*, *c*, *d*, *d*). In their descent they gradually lose their spiral and other vessels, so that when they terminate at the circumference they consist chiefly of liber cells bound together by parenchyma. The *rind* or *false bark* (*fig.* 120, *b*) of Endogenous stems is thus chiefly formed of the ends of the fibro-vascular bundles, and hence we see the principal reason why this rind cannot be separated, as the bark of Exogenous stems, from the tissues beneath.

FIG. 130.

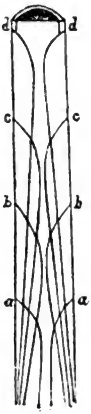


Fig. 130. Diagram showing the course of the fibro-vascular bundles of a Monocotyledonous stem. *a*, *b*, *c*, *d*. Fibro-vascular bundles.

It follows from the mode of growth of the fibro-vascular bundles, as indicated above, that the term *endogenous*, applied to Monocotyledonous stems, is not altogether correct, as the bundles are only endogenous for a portion of their course, terminating as they do ultimately at the circumference. On this account the name endogenous has been generally discarded of late years by botanists, who use instead that of *monocotyledonous*, a term, as already noticed (page 74), derived from the fact that the embryo of plants which possess such stems has but one cotyledon.

As the fibro-vascular bundles of an endogenous stem, in the course of their successive development, are always directed at first towards the centre, it must necessarily follow that those previously formed will be gradually pushed outwards, for which reason the outer part of a transverse section will always exhibit a closer aggregation of bundles than the inside (*figs.* 120, *f*, and 129, A, *b*, *c*, *d*). In such stems, therefore, the hardest part is on the outside, and the softest inside, directly the reverse of what occurs in those of exogenous growth. The lower portion of such stems also, in consequence of the descent of the fibro-vascular bundles, the constituents of which become, moreover, more or less thickened in their interior, will be harder than the upper. The rind in like manner, at the lower part, will become harder, from the greater number of liber-cells which terminate in it. As endogenous stems increase in diameter, partly by the deposit of fibro-vascular bundles in their interior, and partly by the general development of the parenchymatous tissue in which they are placed, it follows that as soon as the rind has become thus hardened by the liber-cells, and other causes, it is not capable of further distension, and the stem will consequently become at length choked up by the bundles which continue to descend, and further growth is then impossible. It is evident, therefore, that endogenous stems, unlike those of exogenous growth, cannot increase in diameter beyond a certain limit, and that from the same causes also they cannot live beyond a certain age.

Growth by Terminal Buds.—In Palms (*fig.* 131, 1), and most commonly in other Monocotyledonous plants, there are no branches, the stems of such plants having no power of forming lateral buds, from which branches can alone be produced (see page 101). These plants, which frequently rise to the height of 150 feet or more, therefore, grow simply by the development of a terminal bud, which when it unfolds crowns the summit with a tuft of leaves, which are commonly of a great size. Monocotyledonous stems are consequently exposed throughout their whole length to, as far as possible, the same influences as regards their increase in diameter, and we find accordingly that, as a rule, such stems are almost uni-

FIG. 131.

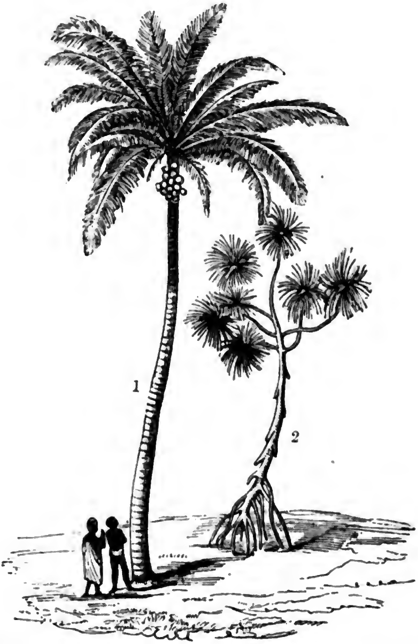


Fig. 131. 1. Unbranched stem of the Cocoa-nut Palm (*Cocos nucifera*). 2. Branched stem of *Pandanus odoratissimus*. The figures are placed at the base to give some idea of the height of the trees.

formly cylindrical from below upwards, being of the same diameter throughout (*fig.* 131, 1), instead of conical as in trees of exogenous growth. In such plants, therefore, the destruction of the terminal bud necessarily leads to their death, as they are then deprived of all further mode of increase. In some Monocotyledonous trees, however, more than one bud is developed; thus in the Doum Palm of Egypt two buds are formed, so that the stem is forked above (*fig.* 132); each branch again developes two other buds at its apex in like manner, and this mode of growth is continued with the successive branches, which are therefore also forked. In other Monocotyledonous plants we have lateral buds formed as in those of Dicotyledons; thus this is the case in the Screw Pine (*fig.* 131, 2); and as the lower part of such stems receives more fibro-vascular bundles than the upper they are necessarily larger in their diameter

FIG. 132.

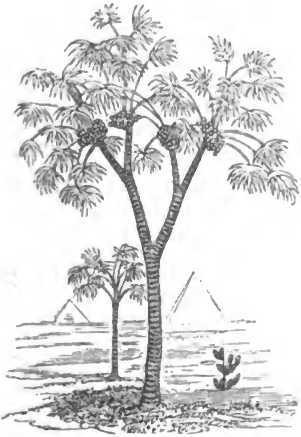


Fig. 132. The Doum Palm of Egypt (*Hyphæne thebaica*), showing forked stem and branches.

at their base, and thus these are conical or taper upwards like those of Dicotyledonous plants.

Some Monocotyledonous stems present an anomalous structure; thus, in most Grasses, the stem is hollow (*fig.* 133, *a*), except at the nodes, *b*, where the leaves arise, at which points partitions are formed across the cavity, by which it is divided into a number of separate portions. Such stems when examined at their first development present the usual Endogenous structure, but in consequence of their growth in diameter taking place more rapidly than new matter can be deposited in their interior, the central tissue becomes ruptured, and they soon become hollow.

FIG. 133.

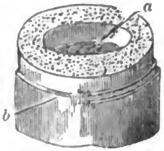


FIG. 134.

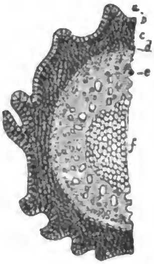


Fig. 133. Transverse section of the stem of the common Reed. *a.* Cavity closed at the bottom by a partition. *b.* Annular scar indicating the point (*node*) where the leaf was attached.——*Fig.* 134. Section of the underground stem of a species of Sarsaparilla. *a.* Epidermal tissue. *b, c, d.* The cortical portion. *e.* Woody zone. *f.* Central parenchyma.

In the stems of some other Monocotyledonous plants we have a more striking deviation from the ordinary structure. Thus the species of Sarsaparilla and some allied plants have aerial stems which are strictly endogenous in structure, and underground stems which have the fibro-vascular bundles arranged in a ring (*fig.* 134, *e*), around a central parenchyma, *f*, like the wood about the pith of an Exogenous stem: such fibro-vascular bundles have, however, no cambium-layer like those which form the rings of wood of an Exogenous stem, and have consequently no power of indefinite increase like them.

There is nothing in the internal structure of Endogenous stems by which we can ascertain the age of Monocotyledonous trees as in those of Exogenous structure; and although other characters may, in a few cases, enable us to ascertain the age of some Monocotyledonous trees, as Palms, these are of such limited application, that we must come to the conclusion there are no trustworthy means of determining the age of Monocotyledonous plants.

C. ACROGENOUS OR ACOTYLEDONOUS STEM.—The simplest form of stem presented by Acotyledonous plants is that seen in Liverworts (*fig.* 7), and in Mosses (*fig.* 8). In such a stem we have no vessels, but the whole is composed of ordinary parenchyma, with occasionally a central cord of slightly elongated cells with somewhat thickened walls. In the stems of Club-mosses and Horsetails (*fig.* 10), we have the simplest forms of Acrogenous stems, which contain the peculiar fibro-vascular bundles (*simultaneous*) which are their especial characteristics. The composition of these bundles and their mode of growth have been already described (see page 74). The vessels found in the fibro-vascular bundles of the Lycopodiaceæ are *spiral*, and in those of the Equisetaceæ *annular*. All Acotyledonous stems grow by additions to their apex, and hence the term *Acrogenous*, or summit-growers, which is applied to them.

In the Ferns we have the Acrogenous stem in the highest state of development. The Ferns of this country are, however, but insignificant specimens of such plants, for in them the stem merely runs along the surface of the ground, or burrows beneath it, sending up its leaves, or *fronds* as they are commonly called, into the air, which die down yearly (*fig.* 11). In warm regions, and more especially in the tropics, we find such plants much more highly developed. Here the stem rises into the air to the height of sometimes as much as forty feet, and bears on its summit a tuft of fronds. In their general appearance externally these Tree-ferns have great resemblance to Monocotyledonous trees, not only in bearing their foliage like them at the summit, but also in producing no lateral branches, and being of uniform diameter from near their base to their apex.

The outside of the stem of a Fern is marked with a number of *scars*, which have a more or less rhomboidal outline (*fig.* 135); and present on their surface darker-

FIG. 135.

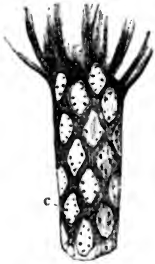


FIG. 136.

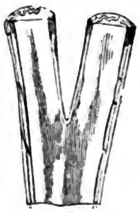


Fig. 135. Rhizome of Male Fern (*Aspidium Filix-mas*), marked externally by rhomboidal scars, which present dark-coloured projections, *c*.——*Fig.* 136. Vertical section of the forked stem of a Tree-fern.

coloured spots, *c*, which appearance is produced by the rupture of the fibro-vascular bundles proceeding to the leaves, by the separation of which organs the scars are produced

Upon making a transverse section of a Tree-fern, we observe, as we have already briefly noticed (see page 72), the following parts:—Thus in the centre, when young, a mass of parenchyma (*fig.* 121, *m*), the cells of which have thin walls; but in old stems this central parenchyma is destroyed, so that the stem becomes hollow. Towards the outside of this parenchyma, and just within the rind, we find the so-called wood, which is arranged in the form of irregular, sinuous, or wavy plates, *v*,*v*,*v*. These masses of wood have generally openings between them, by means of which the parenchyma beneath the rind and that of the centre of the stem communicate; but in other cases they touch each other at their margins, and thus form a continuous circle within the rind. These woody masses consist of simultaneous fibro-vascular bundles (page 74), the vessels of which are chiefly scalariform in their character; these are situated in the centre of the bundles, where they may be readily distinguished by their pale colour (*fig*. 121, *v*, *v*, *v*). External to them are usually a few layers of parenchymatous cells, which contain starch in the winter, and amongst which are situate some wide *lattice-cells*. The whole is surrounded by a single layer of cells, the walls of which are more or less lignified and dark coloured, thus constituting the tissue termed *sclerenchyma*, and forming what has been called the *bundle-sheath*. The tissues external to the fibro-vascular bundles constitute collectively what has been termed the rind (*fig*. 121, *e*).

We have already stated that Tree-ferns have no branches. This absence of branches arises from their having, like Palms, no lateral buds: and hence the cylindrical form of stem which is common to them as with the stems generally of Monocotyledonous plants. Some Ferns, however, become forked at their apex (*fig*. 136); which forking is produced by the division of the terminal bud into two, from each of which a branch is formed (see page 104). But such branches are very different from those of dicotyledonous stems, which are produced from lateral buds, for, as they arise simply from the splitting of one bud into two, the diameter of the two branches combined is only equal to that of the trunk, and in all cases where the stems of Acotyledonous plants branch, the diameter of the two branches combined is only equal to that of the axis from whence they are derived. As Acotyledonous stems only grow by the development of a terminal bud, the destruction of that bud necessarily leads to their death. There is nothing in the internal structure or external appearance of such stems by which we can ascertain their age.

2. BUDS AND RAMIFICATION.—We have already seen that the presence of leaves and leaf-buds is the essential characteristic by which a stem may be distinguished from a root. The leaves will be treated of hereafter, but we have now to describe the nature of leaf-buds, and the mode in which branches are formed.

A. LEAF-BUDS OR BUDS.—Under ordinary circumstances we have developed in the axil of every leaf a little more or less conical body called a leaf-bud, or simply a bud (*fig*. 137, *a*, *a*). In like manner, the apex of a stem, at well as of all its divisions which are capable of further elongation, is also terminated by a similar bud (*fig*. 139). In a Dicotyledonous plant each bud, whether lateral or terminal, is produced by an elongation of the parenchymatous system of the stem or one of its divisions, and consists at first of a minute conical central parenchymatous mass (*fig*. 138, *i*), which is connected with the pith, *a*; around this spiral and other vessels and wood-cells are soon developed, also in connexion with similar parts of the wood, *b*, *b*; and on the outside of these, in a parenchymatous mass which ultimately becomes the bark, we have little conical cellular projections developed, which are the rudimentary leaves. As growth proceeds these parts become more evident, and a little more or less conical body is ultimately produced at the apex of the stem or branch (*fig*. 139), or laterally in the axil of the leaves, *c*, and the formation of the bud is completed. In like manner the buds of Monocotyledons and Acotyledons are connected with both the parenchymatous and fibro-vascular systems of their stems; but in these plants, as we have seen, there are, as a general rule, no lateral buds.

The buds of temperate and cold climates, which remain dormant during the winter, and are exposed therefore to all its rigours, have generally certain protective organs developed on their outer surface in the form of modified leaves, or parts of leaves, which are commonly called *scales* or *tegmenta.* These are usually of a hardened texture, and are sometimes covered with a resinous secretion, as in the Horsechestnut; or with a dense coating of soft hairs, as in some Willows. Buds thus protected are termed *scaly*; these scales have only a temporary duration, falling off as soon as the growth

FIG. 137.

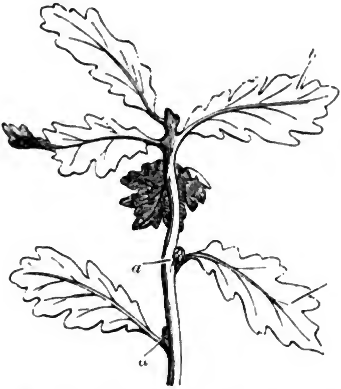


FIG. 138.

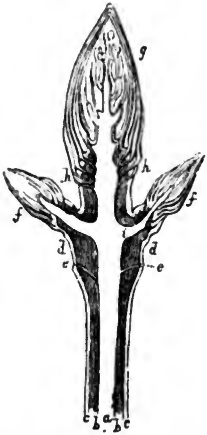


Fig. 137. Branch of Oak with alternate leaves and leaf-buds in their axils. *a, a.* Buds. *b, b.* Leaves.——*Fig.* 138. Longitudinal section of the end of a twig of the Horsechestnut (*Æsculus Hippocastanum*), before the bursting of the bud. After Schleiden. *a.* The pith. *b, b.* The wood. *c, c.* The bark. *d, d.* Scars of leaves of former years. *e, e.* The fibro-vascular bundles of those leaves. *f, f.* The axillary buds of those leaves, with their scales and fibro-vascular bundles. *g.* Terminal bud of the twig ending in a rudimentary flowering panicle. *h, h.* Scars formed by the falling off of the lowest scales of the bud, and above these may be seen the closed scales with their fibro-vascular bundles. *i.* Parenchyma leading from the pith, *a*, into the axillary buds, *f, f.*

of the bud commences in the spring. In the buds of tropical regions, and those of herbaceous plants growing in temperate climates, which are not thus exposed to the influence of a winter, such protective organs would be useless, and are accordingly absent, and hence all the leaves of these buds are nearly of the same character. Such buds are called *naked*.

The bud thus contains all the elements of a stem or branch; in fact, it is really the first stage in the development of these parts, the axis being here so short that the rudimentary leaves are closely packed together, and thus overlap one another. When growth commences in the spring, or whenever vegetation is reanimated, the internodes or spaces between the leaves become developed (*fig.* 140, *d*, *d*, *d*), and these therefore become separated from each other, *c*, *c*, *c*, and thus the stem or branch increases in length, or a new axillary branch is

FIG. 139.

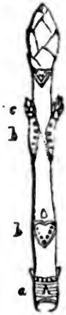


FIG. 140.

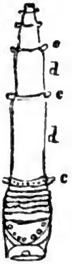


FIG. 141.

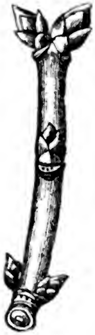


Fig. 139. A shoot one year old of the Horsechestnut, with terminal bud. *a*. Scar produced by the falling off of the bud-scales of the previous year. *b*, *b*. Scars caused by the falling off of the petioles of the leaves of the present year, with buds, *c*, in their axils.——*Fig.* 140. Diagram to illustrate the growth of the shoot from the bud. *c*, *c*, *c*. The nodes where the leaves are situated. *d*, *d*. The internodes developed between them.——*Fig.* 141. Shoot of the Lilac (*Syringa vulgaris*), showing suppression of the terminal bud, and two lateral buds in its place.

formed. In other words, the leaves, which in a bud state overlap one another and surround a growing point or axis, by the elongation of the internodes of that axis become separated and dispersed over a branch or an elongation of the stem, much in the same way as the joints of a telescope become separated from one another by lengths of tube when it is drawn out. The branch, therefore, like the bud from which it is formed, necessarily contains the same parts as the axis upon which it is placed, and these parts are also continuous with that axis, with the exception of the pith, which, although originally continuous in the bud state, ultimately becomes separated by the development of tissue at the point where the branch springs from the axis. But when a branch becomes broken off close to the wood, and there are no buds upon it to continue its growth, it becomes ultimately enclosed by the successive annual layers of wood, and thus a *knot* is formed.

It follows, therefore, from the nature of buds, that a Dicotyledonous plant is really made up of a number of similar parts or buds, which have been called *phytons*, and which are developed in succession, one upon the summit of the other. Hence, by the development of a terminal bud the stem or branch increases in height or length; and by those situated laterally new branches are produced. A tree may thus be considered as a compound body, formed of a series of individuals which mutually assist one another, and benefit the whole mass to which they belong. In Dicotyledonous trees, which form lateral or axillary buds, the destruction of a few branches is of no consequence, as they are soon replaced; but in Palms, and most other Monocotyledonous trees, and also in those of Acotyledons, which develop only from terminal buds, the destruction of these under ordinary circumstances, as we have seen (pages 93 and 98), leads to their death.

The buds, or similar parts, of which a tree, or other Dicotyledonous plant, may thus be shown to be made up, being thus distinct individuals, as it were, in themselves, are also capable of being separated from their parents and attached to other individuals of the same, or even of nearly allied species; or a branch with one or more buds upon it may be bent down into the earth. The operations of Budding, Grafting, and Layering depend for their success upon this circumstance; and in some plants buds naturally separate from their parents, and produce new individuals. These operations are of great importance in horticulture, because all plants raised by such means propagate the *individual peculiarities* of their parents, which is not the case with those raised from seed, which have merely a *specific identity.*

FIG. 142.

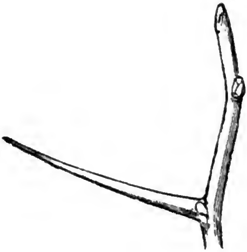


FIG. 143.

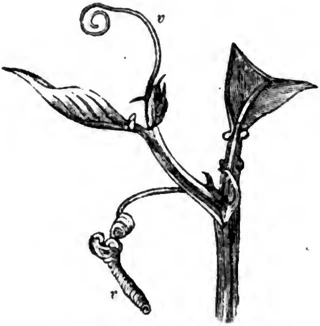


Fig. 142. Spine of a species of Thorn.——*Fig.* 143. A portion of the stem of *Passiflora quadrangularis.* *v, v.* Tendrils.

It sometimes happens that a leaf-bud, instead of developing as usual, so as to form a symmetrical leaf-bearing branch, becomes arrested in its growth, and forms a hardened projection terminating in a more or less acute point, and usually without leaves, as in Thorns (*fig.* 142), and many other plants. Such an irregularly-developed branch is called a *spine* or *thorn.*

That spines are really modified branches is proved not only by their structure, which is exactly the same as the stem or branch upon which they are placed; but also by their position in the axil of leaves; by their sometimes bearing leaves, as in the Sloe; and by their being frequently changed into ordinary leaf-bearing branches by cultivation, as in the Apple and Pear. Spines are also frequently confounded with prickles, already described, but they are readily distinguished from these by their structure and connexion with the internal parts of the stem; the prickles being merely formed of hardened parenchyma, arising immediately from, and in connexion only with, the epidermal tissue and layer of cells beneath.

Another irregularly developed branch is the *tendril* or *cirrhus*; this term is applied to a thread-like leafless branch, which is twisted in a spiral direction, as in the Passion-flower (*fig.* 143, *v*, *v*). It is one of those contrivances of nature by means of which weak plants are enabled to rise into the air by attaching themselves to neighbouring bodies for support.

B. Ramification or Branching.—In the same way as branches are produced from buds placed on the main axis or stem, so in like manner from the axils of the leaves of these branches other buds and branches are formed; these again will form a third series, to which will succeed a fourth, fifth, and so on. The main divisions of the stem are called *branches*, while the smaller divisions of these are commonly termed *twigs*. The general arrangement and modifications to which these are liable are commonly described under the name of *ramification* or *branching*, which may be defined as the lateral development of similar parts. Thus the divisions of a stem or root are branches; but the lateral development of leaves, hairs, or other dissimilar parts from a stem, is not branching.

There are two principal types of branching, the *monopodial* and the *dichotomous*. Thus, when the axis continues to develop in an upward direction by a terminal bud or growing point, so as to form a common *foot* or *podium* for the branches, which are produced from below upwards, or *acropetally* from lateral buds (*fig.* 137, *a*, *a*), the branching is called *monopodial.* This is, with rare exceptions, perhaps the universal system of branching in the Angiospermia. But when the terminal bud or growing point bifurcates, and thus produces two shoots, so that the foot or podium bears two branches arranged in a forked manner (*fig.* 144),

FIG. 144.

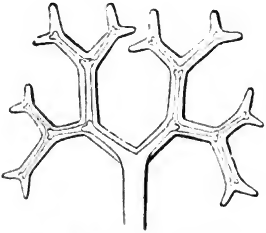


FIG. 145.

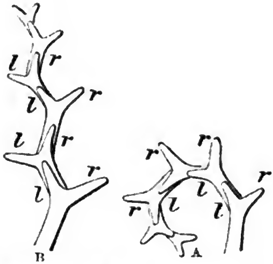


Fig. 144. Diagram of normal or true dichotomous branching, showing the two branches equally developed in a forked manner, and each branch dividing in succession in a similar way.——*Fig.* 145. Diagrams of sympodial dichotomous branching. A. Bostrycoid or Helicoid dichotomy. B. Cicinal or Scorpioid dichotomy. In A the left-hand branches, *l*, *l*, *l*, of successive dichotomies are much more developed than the right, *r*, *r*, *r*, *r*. In B the left-hand branches, *l*, *l*, and those of the right-hand, *r*, *r*, are alternately more vigorous in their growth. After Sachs.

the branching is termed *dichotomous.* This form is common in many of the Cryptogamia (*fig.* 136).

In dichotomous branching we have also two forms, one which is termed *true* or *normal dichotomy*, in which the two branches continue to develop equally in a forked manner—that is, each becomes the podium of a new dichotomy (*fig.* 144); and a second, in which one branch grows much more vigorously than the other, when it is called *sympodial* (*fig.* 145, A and B). In this latter case, owing to the unequal growth of the branches, the podia of successive bifurcations form an axis which is termed the *pseud-axis* or *sympodium*, on which the weaker fork-branches or bifurcations appear as lateral branches (*fig.* 145, A, *r*, *r*, *r*, *r*, and B, *r*, *l*, *r*, *l*, *r*). This branching might at first sight be confounded with the monopodial form, where we have a continuous axis giving off lateral branches; but it differs in the fact that here the apparent primary axis consists of a succession of secondary axes.

In sympodial branching, again, the sympodium may be either formed of the fork-branches of the same side (left or right) of successive dichotomies (*fig.* 145, A, *l*, *l*, *l*); or it may consist alternately of the left and right fork-branches or bifurcations (*fig.* 145, B, *l*, *r*, *l*, *r*). In the former case it is called *helicoid* or *bostrycoid dichotomy*; in the latter, *scorpioid* or *cicinal dichotomy*.

Of the monopodial branching there are also two forms, the *racemose* and the *cymose*. In the first the primary axis continues to develop upwards and gives off acropetally lateral branches from axillary buds; which also give off lateral branches in a similar manner; but in the second form the lateral axes at an early age develop much more vigorously than the primary axis and become more branched than it. It is in this way—that in some plants, by the suppression of the terminal bud and the subsequent vigorous growth of the closely arranged lateral buds, forming two shoots apparently radiating from a common point, as if caused by the division of the terminal bud, as in true dichotomous branching,—an apparent but false dichotomy is produced, which is called a *dichasium* or *false cyme*. This suppression of the terminal bud may occur naturally, as in the Lilac (*fig.* 141); or accidentally, from frost or other injury.

All lateral or axillary buds are called *regular* or *normal*, and their arrangement in such cases is necessarily the same as that of the leaves. Again, as branches are formed from buds thus placed, it should follow that their arrangement should also correspond to that of the leaves. This corresponding symmetry, however, between the arrangement of the branches and that of the leaves is interfered with from various causes; the following of which are the more important Thus, in the first place, by many of *the regular buds not being developed.* Secondly, by the development of other buds which arise irregularly at various other points than the axils of leaves, and which are called, from their abnormal origin, *adventitious.*

These adventitious buds may be produced on any part of the stem or branches, or on the margins (*fig.* 146, *b*, *b*), or surface of leaves; or, in some trees, instead of being developed on the outside of the stem or branch, they are enclosed in the bark; such have been called *embryo-buds* or *embryo-nodules.* They may be readily observed in the bark of certain trees, such as the Cork-oak and the Cedar, in which they produce externally little swellings, which, when examined, are found to be owing to the presence of these nodules, which have a more or less irregular ovoid (*fig.* 147) or spheroidal form, and woody texture. When leaves bear adventitious buds they are called *proliferous.*

FIG. 146.

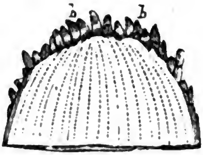


FIG. 147.

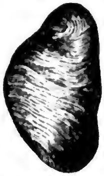


Fig. 146. End of the leaf of *Malaxis paludosa*, with buds, *b*. *b*, on its margins.——*Fig.* 147. Embryo bud or embryo-nodule of the Cedar.

A third cause of irregularity in the distribution and appearance of branches arises from the multiplication of buds in the axils of leaves. Thus, instead of one bud, we have in rare cases two, three, or more, thus situated; such are called *accessory buds*. These buds may be either placed one above the other, or side by side (*fig.* 148, *a*). In some trees, again, as the Larch and Ash, and frequently in herbaceous plants, these accessory buds, instead of forming separate branches, become more or less united, and the branches thus produced then assume a more or less flattened or thickened appearance; these abnormal branches are commonly called *fasciated*. Such branches are also, in some cases, produced by a single bud developing in an irregular manner.

FIG. 148.

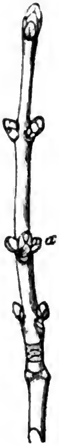


Fig. 148. Branch of a species of Maple with three buds, *a*, placed side by side.

3. OF THE FORMS AND KINDS OF STEMS AND BRANCHES.—*A.* FORMS OF STEMS.—In form the stem is usually more or less cylindrical, while in other cases it becomes angular, and in some plants, particularly in those of certain natural orders, as the Cactaceæ, Orchidaceæ, and Euphorbiaceæ, it assumes a variety of other forms, as rounded, oval, globular, more or less flattened, columnar, &c.

In general, stems possess a firm texture, and can therefore readily sustain themselves in an upright direction; but at other times they are too weak to support themselves, and then either trail along the ground, or become erect by attaching themselves to other plants or neighbouring objects. In such cases, if they trail on the ground (*figs.* 152 and 153) they are said to be *prostrate*. Or, if they take an erect position and cling to neighbouring plants or objects for support, they are called *climbing* if they proceed in a more or less straight direction, as in the Passion flower (*fig.* 143) and Ivy (*fig.* 149); or, if they twist round other bodies in a spiral manner, they are said to be *twining*, as in some Convolvuli (*fig*. 151), and the Honeysuckle (*fig*. 150).

The stem has also received many names according to its nature. Thus it is called a *caulis* in plants when it dies down annually to the surface of the ground; a *trunk*, as in trees, where it is woody and perennial; a *culm*, as in most Grasses and Sedges, where it presents a jointed appearance; and a *caudex*, as in Tree-ferns and Palms.

FIG. 149.

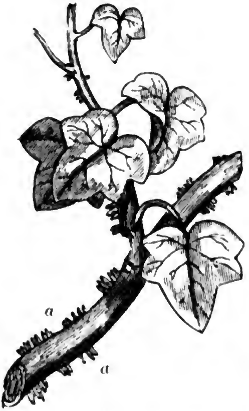


Fig. 149. Climbing stem of the Ivy. *a, a*. Aerial roots.

FIG. 150.

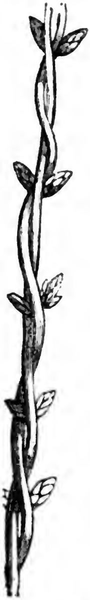


Fig. 150. Twining stem of Honeysuckle.

FIG. 151.

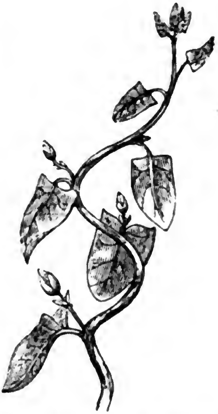


Fig. 151. Twining stem of a species of *Convolvulus*.

Herbs, Shrubs, and Trees.—From the nature, duration, and mode of branching of stems, plants have been arranged from the earliest periods in three divisions.

called, respectively, *Herbs*, *Shrubs*, and *Trees*. Thus those plants which have stems that die down annually to the surface of the ground, are called *herbs*; these are also further characterised as *annual*, *biennial*, and *perennial*. Thus they are *annual*, when they only live through one season, that is, between spring and autumn; *biennial*, when they arise from seed in one season, and die in the second, after producing flowers, fruit and seed; and *perennial*, when they germinate from seed in one season, and continue to live through a succession of years, and annually send up an herbaceous stem or branches. But when the plants have *permanent* aerial woody stems, they are called *trees* or *shrubs*, according to circumstances. Thus the term *tree* is applied if the branches are perennial and arise from a trunk. But when the branches are perennial and proceed directly from, or near to, the surface of the ground without any trunk, or where this is very short, a *shrub* is formed; and this, when low and branched very much at the base, is called a *bush*. The term *undershrub* is also applied to a small shrub which is intermediate in its characters between an ordinary shrub and an herb; thus, when some of its branches generally perish annually, while others are more or less permanent.

B. KINDS OF STEMS AND BRANCHES.—We have seen that the stem, when first developed, always takes a diametrically opposite direction to that of the root. In most instances this direction is continued more or less throughout its life, but in other plants the terminal bud either acquires an irregular direction, and the stem runs along, or remains under, the surface of the ground; or it perishes altogether at a very early period, and an axillary branch takes its place, which also, by developing laterally, will likewise continue near the surface of the ground or burrow beneath it. In this manner many irregular kinds of stem are produced, of which some of the more important will be now noticed.

Of these one of the commonest is the *Rhizome* or *Rootstock* (*fig.* 152). This is a prostrate thickened stem or branch which creeps along the surface of the ground, or more generally partly beneath it, and gives off buds from its upper surface and roots from its lower. Such a stem is found in the Fern, Iris, Sweet Flag, and many other plants. These stems often creep for a long distance, and have their upper surface marked by scars produced by the falling off of former leaves or aerial stems or branches, by which character they may be commonly distinguished, even when in a dried state, from roots. In some cases these rhizomes are placed in a vertical direction, and they then bear a great resemblance to roots, as in the Devil's-bit Scabious (*Scabiosa succisa*), where such a rhizome is commonly known as a *præmorse root.*

FIG. 152.

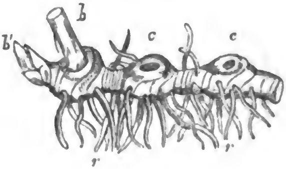


Fig. 152. A portion of the rhizome of the Solomon's Seal (*Polygonatum multiflorum*). *b.* Remains of flowering stem of the present year. *b'.* Terminal bud. *c, c.* Scars produced by the decay of the flowering stems of the two preceding years. *r, r.* Roots.

Another kind of irregular stem is seen in the Strawberry Plant, where the main stem sends off from its base a slender lengthened prostrate branch (*fig.* 153, *a'*), which gives off at its end leaves, *r*, and roots, *f*, and thus produces a new plant, which in like manner extends itself. This kind of stem is called a *runner*.

A third kind of stem is called a *stolon.* This is a branch given off above the surface of the earth, but which ultimately proceeds downwards to it, sending roots into the ground and a stem upwards into the air, and thus forms a new individual. The Currant, Gooseberry, and other plants, multiply in this way. All such plants are said to be *stoloniferous.* Gardeners imitate this natural formation of new individuals, when they lay down a branch into the earth, from which a new plant is ultimately formed; this process is technically called *layering.*

The above described kinds of stem are either entirely aerial, or partly developed in the air and partly under ground; the remaining kinds to be noticed are essentially subterranean, like roots, and they are thus designated in common language. They are distinguished, however, from roots, either by the presence of buds, or by scales or modified leaves, or by the presence of scars on their surface which are produced by the falling off of former leaves or buds. The different kinds of aerial stems described above, when partially subterranean, may be also distinguished in a similar manner from roots.

FIG. 153.

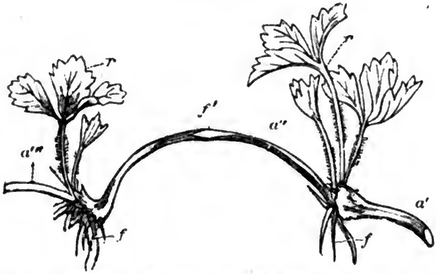


Fig. 153. A portion of the common Strawberry plant. *a'*. An axis producing a tuft of leaves at its extremity, the upper of which, *r*, are well developed and green, and the lower rudimentary. From the axil of one of the latter a second axis or runner, *a''*, arises, bearing a rudimentary leaf, *f'*, near the middle, and a cluster of leaves, *r*, at its end. *a'''*. A third axis produced in a similar manner to the former. *f*, *f*. Roots.

The Creeping Stem or Soboles (*fig.* 154).—This kind of stem is called, in common language, a *creeping-root.* It is a slender branch which runs along beneath the surface of the earth, emitting roots from its lower side, and buds from its upper, in the same manner as the rhizome, and it is considered by many botanists as a variety of that stem. The only differences existing between the creeping stem as defined above and the rhizome, are its more slender form, its commonly greater length, and its entirely subterranean course. The Sand Sedge or *Carex arenaria* (*fig.* 154), and the Couch Grass (*Triticum repens*), afford good examples of this stem.

FIG. 154.

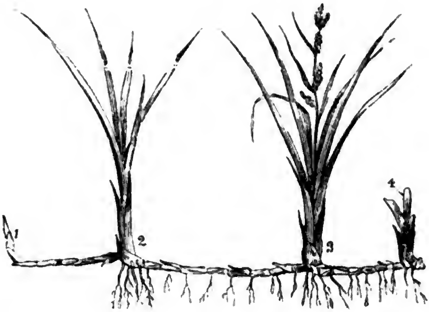


Fig. 154. Creeping stem of the Sand Sedge (*Carex arenaria*). 1. Terminal bud by which the stem continues to elongate. 2, 3, 4. Shoots produced from subterranean buds.

The Tuber (*fig.* 155).—This is a subterranean stem or branch, arrested in its growth, and excessively enlarged by the deposition of starch or other nutritious substance in its tissue. It has upon its surface a number of little buds, or eyes as they are sometimes called, from which new plants are ultimately formed. The presence of these buds indicates its nature as a kind of stem or branch. The Potato and Jerusalem Artichoke (*fig.* 155), are good illustrations of tubers. This stem-like nature of the tuber is also clearly proved by the practice commonly adopted for propagating potatoes, the tuber being cut into pieces, each piece containing one or more buds. The buds of these pieces, when placed under favourable circumstances for development, are at first nourished by the matter which surrounds them, and they are thus enabled to put forth roots, and obtain nourishment for themselves, and in this manner to form independent plants.

The tubercules of certain terrestrial Orchids and other plants (*fig.* 170–172), which are described by us as enlarged roots, are considered by some botanists as tubers. The tuber, however, as defined above, is well characterised, and, in practice at least, should be distinguished from them.

FIG. 155.

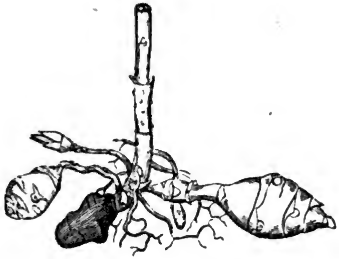


Fig. 155. Tubers of the Jerusalem Artichoke (*Helianthus tuberosus*).

The Bulb.—This is a shortened, usually subterranean stem or branch, generally in the form of a rounded or flattened plate or disc (*figs.* 156 and 157, *a*), which bears on its surface a number of fleshy scales or modified leaves; or it may be considered as a subterranean bud of a scaly nature, which sends off roots from below (*fig.* 157, *b*), and a flowering stem upwards (*figs.* 156 and 157, *d*). The bulb is only found in Monocotyledonous plants, as in the Lily (*figs.* 156 and

157) and Onion (*fig.* 158). The scales of a bulb, like the ordinary leaves of a branch, have the power of developing in their axils new bulbs; these are called by gardeners *cloves*, and their presence is an additional proof of the analogy of a bulb to a branch or bud.

There are two kinds of bulbs commonly distinguished by botanists, namely, the *tunicated* (*fig.* 158), and the *scaly* (*figs.* 156 and 157). The *tunicated bulb* is well seen in the Onion (*fig.* 158). In this kind of bulb the inner scales, which are thick and fleshy, and enclose one another in a concentric manner, are covered externally by thin and membranous ones, which form a covering or *tunic* to them, and hence the name *tunicated* or *coated*, which is applied to it. In the *scaly*, or *naked bulb* as it is also called, there are no outer dry scales; but it is entirely composed of thick, fleshy, more or less flattened ones, which simply overlap one another.

FIG. 156.

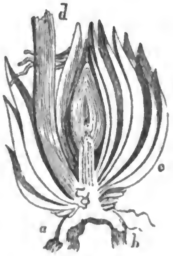


FIG. 157.

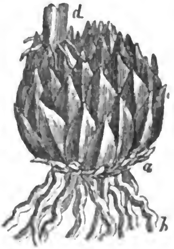


Fig. 156. Vertical section of the scaly bulb of the Lily.——*Fig.* 157. Scaly bulb of the Lily. (The letters refer to the same in both figures.) *a.* Shortened axis or stem. *b.* Roots. *c.* Scales. *d.* Flowering stem.

In the axils of the leaves of certain plants, such as some species of Lily (*fig.* 159, *a*, *a*), and Pilewort (*Ranunculus Ficaria*), small conical or rounded fleshy bodies are produced, which are of the nature of bulbs, and are hence called *aerial bulbs* from their position, or from their smaller size, *bulbils* or *bulblets.* They differ from

FIG. 158.

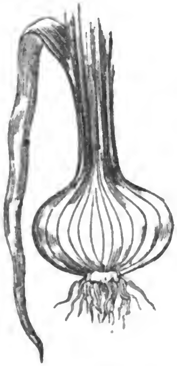


FIG. 159.

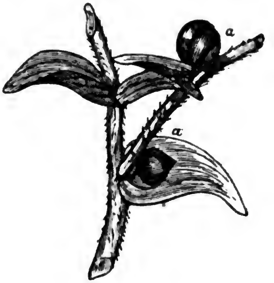


Fig. 158. Tunicated bulb of the Onion.——*Fig.* 159. Stem of a species of Lily (*Lilium bulbiferum*) bearing bulbils or bulblets, *a*, *a*, in the axils of its leaves.

FIG. 160.

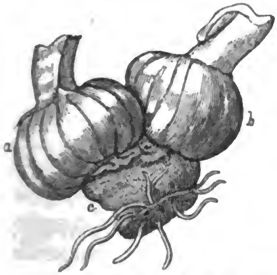


FIG. 161.

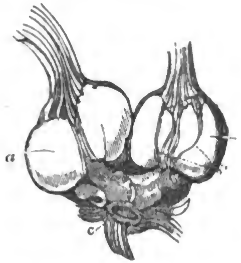


Fig. 160. Corms of *Crocus sativus.* *a*, *b*. The new corms, arising from *c*, the apex of the old or parent corm.——*Fig.* 161. Section of the former. The letters refer to the same parts.

ordinary buds in their fleshy nature, and by spontaneously separating from their parent, and producing new individuals when placed under favourable circumstances; and from true bulbs from their small size and aerial position. These aerial bulbs are not, like true bulbs, confined to Monocotyledonous plants.

FIG. 162.

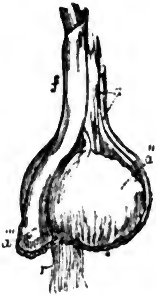


Fig. 162. Colchicum corm. *r.* Roots. *f.* Leaf. *a.* Shrivelled remains of last year's corm. *a''.* Corm of the present year. *a'''.* Commencement of the corm of next year.

The Corm.—This form of stem, like the true bulb, is only found in Monocotyledonous plants, as, for example, the Colchicum (*fig.* 162) and Crocus (*figs.* 160 and 161). It is an enlarged solid subterranean stem, of a rounded or oval figure, and commonly covered externally by a few thin membranous scales. By some botanists it is considered as a kind of bulb, in which the stem or axis is much enlarged, and the scales reduced to thin membranes. Practically a corm may be distinguished from a bulb by its solid nature (*fig.* 161, *a*, *b*), the bulb being formed of flattened imbricated, or concentrically arranged scales. The corm is known to be a kind of stem by producing from its surface one or more buds, in the form of young corms, as in the Crocus (*fig.* 160, *a*, *b*), where they proceed from the apex, or from the side, as in the Colchicum (*fig.* 162, *a'''*).

Section 2. THE ROOT OR DESCENDING AXIS.

THE root is defined as that part of the axis which at its first development takes a downward direction, and hence called the descending axis, avoiding the light and air, and fixing the plant to the soil or to the substance upon which it grows, or suspended in the water when the plant is placed in that medium. That part of the root which joins the stem is called the *base* (*fig.* 166, *c*), and the opposite extremity the apex.

We distinguish two varieties of roots, namely, the *True* or *Primary*, and the *Adventitious* or *Secondary*.

1. TRUE OR PRIMARY ROOT.—The true root, which, except in rare cases, only exists in Dicotyledonous plants (page 124), is formed at first by additions made within the extremity of the radicle of the embryo; and the mode in which it takes place may be thus stated:—Growth commences by the multiplication of cells by division just within the apex of the radicle; the mass of cells thus formed becomes gradually differentiated into three layers, an outer, inner, and intermediate. From the inner layer, which is termed the *plerome* or *procambium*, is subsequently developed the fibro-vascular portion of the root; the cortical layers being formed from the intermediate layer or *periblem*; whilst the outer single layer of cells, known as the *dermatogen*, in addition to giving rise to the epidermis, forms the cap-shaped mass of tissue, called the *root-cap* or *pileorhiza*, by which the growing apex of the root is always clothed. All roots (*fig.* 163, *a*), and the branches of a root grow in length in a similar manner to the radicle as above described; hence roots do not grow throughout their entire length like stems, but only within their extremities, which are continually pushed forward and renewed. Thus the apex of the root is always clothed by a layer of tissue which is known as the root-cap. All the branches of a root are likewise terminated by a similar cap (*fig.* 164, *h*, *h*). This cap forms in fact a sort of protecting shield to the young extremities of the root; and its external cells are commonly thrown off as new cells are formed within them. Roots increase in diameter by the formation of annual layers of wood, much in the same manner as stems.

At first the elongating growing extremities of the root consist entirely of parenchymatous cells (*fig.* 163, *a*); wood-cells and vessels, however, soon make their appearance, and are constantly added to below by the new tissue formed as the root continues to lengthen. When the root is fully developed, these vessels and wood-cells generally form a central mass or wood (*fig.* 164, *f*), in which there is commonly no pith, and no medullary sheath, but the medullary rays exist as in the stem. Roots, however, differ from stems in the arrangement of the parts of their fibro-vascular bundles. Thus, in roots the phloëm or liber-cells alternate with the xylem or woody portions, instead of being placed external to them. Some other minor differences also occur. Externally there is a true bark or cortex (*fig.* 164, *r*, *r*), covered when young by a modified epidermis without stomata, sometimes called *epiblema*, and which is also furnished with hair-like prolongations, termed *root-hairs* or *fibrils* (*fig.* 163, *c*, *c*). The latter

FIG. 163.

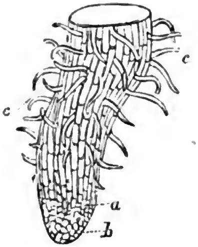


FIG. 164.

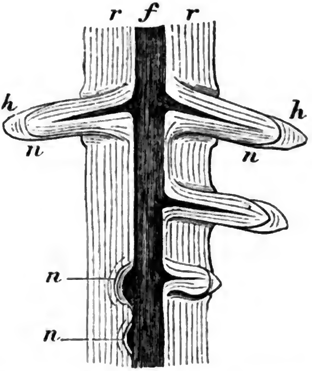


Fig. 163. Young root of the Maple, magnified. *a.* The part where growth is taking place. *b.* The original extremity. *c, c.* Fibrils or root-hairs. After Gray.——*Fig.* 164. Longitudinal section of the root of the common Bean (*Faba vulgaris*), magnified five times. *r, r.* Cortex of the main root. *f.* Fibro-vascular bundles *n, n, n, n.* Lateral roots in different stages, developing from the pericambium, and ultimately bursting through the cortex. *h, h.* Root-cap or pileorhiza of the lateral roots. After Prantl.

are especially evident upon young growing roots, and as these advance in age they perish, while the tissue from which they were prolonged becomes at the same time harder and firmer, and is converted gradually into cork-tissue.

Roots have no leaves, and normally no buds, hence they have no provision for regular ramification; but they appear to divide and subdivide according to circumstances without any definite order; hence while the branches of the stem have a more or less symmetrical arrangement, as already described, those of the root are unsymmetrical. The branches of the root are always developed endogenously (*fig.* 164, *n*, *n*), that is, they are deep-seated, being derived from the pericambium or outer layer of the plerome or procambium. As they increase in length they ultimately push through the tissues which are superficial to them, namely, the cortical layers and epidermis of the main root, which are therefore not continuous with the similar tissues of the branches. The branches are thus merely repetitions of the original axis from which they are developed, and grow, as already noticed, in a similar manner, and, like it, have commonly neither buds nor leaves.

2. Adventitious or Secondary Root.—This name is applied to all roots which are not produced by the direct elongation of the radicle of the embryo; because such roots, instead of proceeding from a definite point as is the case with the true or primary root, are, to a certain extent at least, accidental in their origin, and dependent upon favourable external circumstances for their development. All branches of a true root, except those originally produced from its apex, are of this nature, as are also those of the different modifications of stems, such as the rhizome, runner, stolon, corm, bulb, &c.; those of slips and cuttings of plants, &c.; and those of nearly all Monocotyledonous and Acotyledonous plants. In some plants roots are also developed from the stems or branches of plants in the

air, and are hence called *Aerial Roots*. Such roots are likewise necessarily of an adventitious nature.

The adventitious roots of Monocotyledonous plants make their first appearance as little more or less conical bodies formed by division and subsequent growth of the cells constituting the pericambium or outer layer of the plerome (*procambium*); these soon break through the tissue which envelopes them, and appear externally, at first as parenchymatous elongations, but ultimately having a similar structure to that of a monocotyledonous stem. Where they break through they are surrounded at the base by a kind of sheath or collar called a *coleorhiza* (*fig*. 165, *co*). They also grow by additions within their extremities like true roots, and are terminated like them by a root-cap or pileorhiza,

FIG. 165.

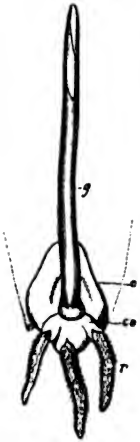


FIG. 166.

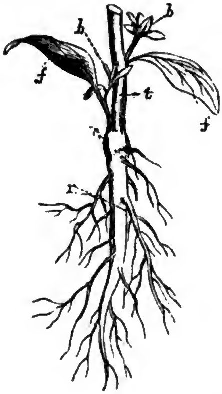


Fig. 165. Germinating embyro of the Oat. *r*. Rootlets, each with a sheath (coleorhiza), *co*, at its base. *c*. Cotyledon. *g*. Young stem.——*Fig*. 166. Lower part of the stem and root of the common Stock. *r*. The tap-root with its branches. *c*. The base of the root or point of union between the stem and root, which has been termed the neck. *t*. The stem. *f*, *f*. Leaves. *b*, *b*. Buds in process of development into branches.

a portion of which, like that of a true root, is thrown off as development takes place behind it, except in certain aquatic plants, as the Duckweed, where it is persistent.

The adventitious roots of Dicotyledons arise in a somewhat similar manner to those of Monocotyledons, making their first appearance as little conical bodies formed from the substance of the pericambium, and ultimately breaking through the bark and appearing on the surface. They also grow by additions within their extremities, and each is protected by a pileorhiza, and has at its base a coleorhiza. They have, under ordinary circumstances, a similar structure to that of true roots.

Adventitious roots generally, like true roots, have no leaves or buds, and when subterranean have no epidermis furnished with stomata; hence when derived from Dicotyledons, they are distinguished from the stem by the same characters as that of the true root. The adventitious roots of Monocotyledons and Acotyledons have a similar structure to their respective stems, as will be afterwards noticed.

Some adventitious roots, such as those called aerial, require a more particular notice. The simplest forms of aerial roots are seen in the Ivy (*fig.* 149, *a*, *a*), and some other climbing plants, where they are essentially intended for mechanical support. But in many other plants the aerial roots which are given off by the stems or branches descend to the ground, and, fixing themselves there, not only act as mechanical supports, but also assist the true root in obtaining food. Such roots are well seen in the Screwpine (*fig.* 131, 2), and in the Banyan or Indian Fig-tree.

Epiphytes.—In some plants, as most Orchids (*fig.* 167, *a*, *a*), and Tillandsias, none but aerial roots are produced, and as these never reach the soil they cannot obtain any food from it, but must therefore draw their food entirely from the air in which they are developed;

hence the name of *air-plants* which is applied to them. They are also called *epiphytes*, because they usually grow upon other plants. The roots of such plants are commonly green, and possess a true epidermis—that is, one with stomata; in which particulars, therefore, aerial roots present exceptions to what is generally observed in other roots. The aerial roots of Orchids are also clothed by a pale-coloured cellular tissue at their extremities, composed of fibrous cells (page 44), to which the name of *velamen radicum* has been given.

FIG. 167.

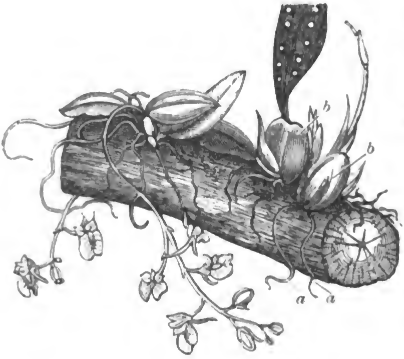


FIG. 168.

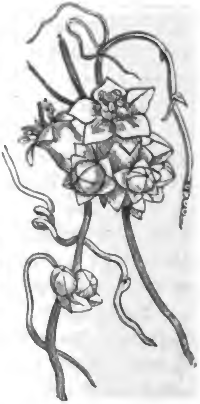


Fig. 167. Orchidaceous plants, to show their mode of growth. *a*, *a*. Aerial roots. *b*, *b*. Pseudobulbs.——*Fig*. 168. Cuscuta or Dodder-plant.

Parasites.—There are also other plants which not only grow upon others, but which, instead of sending their roots into the air and deriving their food from it, as is the case with the epiphytes, send them into the tissues of the plants upon which they grow, and obtain nutriment from them. The plant which they thus penetrate and feed upon is termed their *host*; and their sucking roots are termed *haustoria*. The Mistletoe, Broom-rapes, Dodders (*fig.* 168), may be cited as familiar examples of such plants. These parasites are of various natures; thus some have green foliage, as in the Mistletoe, while many others are pale, or brownish, or possess other tints than green, as the Broom-rapes.

Parasitical plants also vary in the degree of their parasitism; thus the Mistletoe and the greater number of parasites are, so far as their roots are concerned, entirely dependent upon the plants on which they grow for their food. Others, as the Dodders, obtain their food at first by means of ordinary roots contained in the soil; but after having arrived at a certain age, these perish, and they then derive their food entirely from roots which penetrate the plants upon which they grow; others, again, continue throughout their life to derive a portion of their food by means of roots imbedded in the soil.

It will thus be seen that parasites differ from other plants in the fact that they do not live like them entirely on inorganic matters, but derive a portion of, or all, their food in an assimilated state from the plants on which they grow. Thus when green, like the Mistletoe, they obtain a portion of their food, like ordinary plants, from the air; but if of other colours than green, all their food is derived from the plants on which they grow. It must also necessarily happen that parasites, by living partially or entirely upon those on which they are placed, frequently injure, and even destroy them, and in this way great damage is done to Clover, Flax, and other crops in this country and elsewhere.

Besides the parasites just described, there is also another class of plants called *saprophytes*, which, whilst agreeing with ordinary parasites in deriving their food from already formed organic material, differ from this latter class in growing on dead organic substances, and therefore assimilating such matter which is in a state of decomposition or decay. Such plants as *Monotropa* and the greater number of Fungi are examples of saprophytes.

ROOTS OF DICOTYLEDONOUS, MONOCOTYLEDONOUS, AND ACOTYLEDONOUS PLANTS.—The roots of the three great classes of Dicotyledonous, Monocotyledonous, and Acotyledonous plants have certain distinctive characters, which may be briefly summed up as follows:—

1. *Root of Dicotyledonous Plants.*—The root of these plants is formed, as we have seen (page 117), by the direct elongation of the radicle of the embryo from the formation of new tissue just within its apex. Such a mood of root development has been called *exorhizal*, and a root thus formed is termed a *true root.* It follows from this mode of development that the root of a Dicotyledonous plant generally grows downwards, for some distance at least, and hence forms a main trunk or descending axis (*fig.* 166, *r*), from which branches are given off in various directions, in the same manner as such plants have also an ascending axis or stem, *t*, from which its branches arise. Such a root is termed a *tap-root.*

The internal structure has been already described (page 118), and we have there seen that it has commonly, when fully developed, no pith or medullary sheath, and that the fibro-vascular tissue forms therefore a central axis. There are many plants, however, such as the Horsechestnut, where the pith is prolonged downwards for some distance into the root.

2. *Root of Monocotyledonous Plants.*—In these plants the radicle does not itself, except in rare cases, become prolonged to form the root, but it generally gives off above its base one or more branches of equal size, which separately pierce the radicular extremity of the embryo, and become the roots (*fig.* 165, *r*); each of these roots is surrounded at its base, where it pierces the integuments, with a kind of cellular collar termed the *coleorhiza*, *co.* Such a mode of root-development has been termed *endorhizal.* The roots of Monocotyle-

donous plants are therefore to be regarded as commonly *adventitious* or *secondary*.

From their mode of development it rarely happens that the plants of this class have tap-roots, but they have instead a variable number of roots of nearly equal size, which are accordingly termed *compound*.

Aerial roots are very common in Monocotyledonous plants. We have already referred to them in the Screw-pine (*fig.* 131, 2); and in many Palms they are developed in such abundance towards the base of the stem, as to cause this part to assume a conical appearance, which is at once evident by the contrast it presents to the otherwise cylindrical stem of such trees. In its internal structure the root of a Monocotyledon corresponds to that of the stem in the same class of plants.

FIG. 169

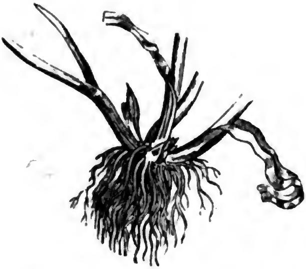


FIG. 170.

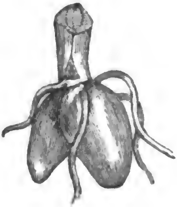


Fig. 169. Fibrous root of a Grass.——*Fig.* 170. Tubercular roots of an Orchis.

3. *Root of Acotyledonous Plants.*—Such plants have no true seeds containing an embryo, but are propagated by spores, from which roots are developed in a very irregular manner; and hence this mode of root-development has been called *heterorhizal.* Such roots are therefore adventitious; and resemble those of Monocotyledonous plants in being compound. Aerial roots are also very common in Acotyledons; indeed,

in Tree-ferns as in many Palms, these roots are so abundant at the base of the stem, that they sometimes double, triple, or still further increase its normal thickness, and hence give to the lower part of such stems a conical form. The internal structure of the root of Acotyledons in all essential characters resembles that of the stem in the same class of plants.

FORMS OF ROOTS.—When a root divides at once into a number of slender branches or rootlets, or if the primary root is but little enlarged, and gives off from its sides a multitude of similar branches, it is called *fibrous*. Such roots occur commonly in annual plants, and may be well seen in annual Grasses (*fig.* 170). When some of the divisions of a root become enlarged so as to form more or less rounded, oval, or ovoid expansions (*fig.* 170), the root is said to be *tuberculated*, and each enlargement is called a *tubercule*. Such a root occurs in various terrestrial Orchids, the Jalap

FIG. 171.

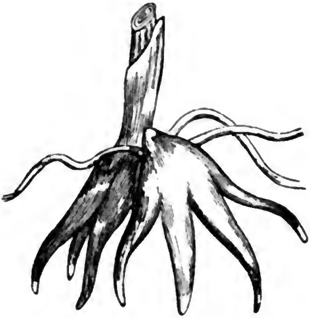


FIG. 172.

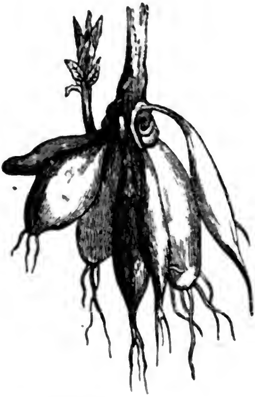


Fig. 171. Palmated tubercules of an Orchis.——*Fig.* 172. Fasciculated root of the Dahlia.

plant, &c. These tubercules should not be confounded with tubers (page 113), which have been already described as subterranean modifications of the stem. The presence of buds on the latter at once distinguishes them. In many Orchids the tubercules are divided at their extremities, so that the whole somewhat resembles the human hand (*fig.* 171); they are then said to be *palmated*; or when a number of tubercules arise from a common point, as in the Dahlia (*fig.* 172), the root is said to be *fasciculated* or *tufted*.

FIG. 173.

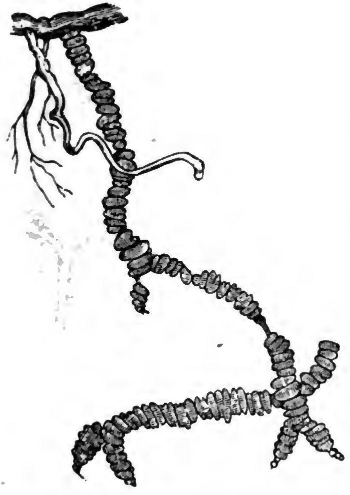


FIG. 174.

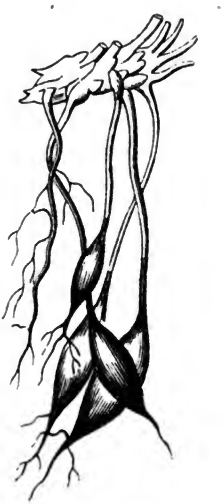


Fig. 173. Annulated root of Ipecacuanha (*Cephaëlis Ipecacuanha*). ——*Fig.* 174. Nodulose root of the common Dropwort (*Spiræa Filipendula*).

When the branches of a root have a number of ring-like expansions on its surface, as in Ipecacuanha, it is *annulated* (*fig.* 173); or when they are enlarged irregularly towards the ends, as in the common Dropwort, the root is *nodulose* (*fig.* 174).

The above forms of roots, with few exceptions, are those which are commonly observed in plants which have no true tap-root; but in the latter case when a tap-root is broad at its base, and tapers towards the apex, it is termed *conical* (*fig.* 175). The roots of Monkshood, Parsnip, and Carrot are familiar examples of this form of root.

FIG. 175.

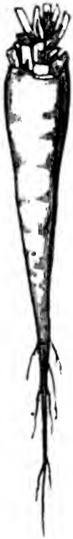


FIG. 176.

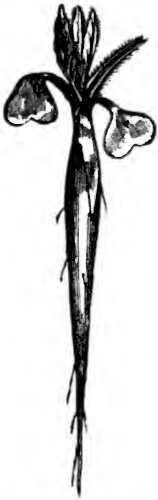


FIG. 177.

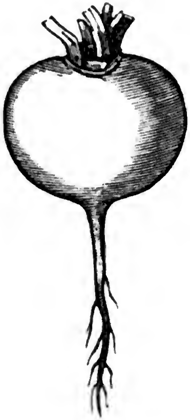


Fig. 175. Conical root of the common Carrot (*Daucus Carota*).——*Fig.* 176. Fusiform root of the common Radish (*Raphanus sativus*). ——*Fig.* 177. Napiform root of the Turnip (*Brassica Rapa*).

When a tap-root swells out a little below its base, and then tapers upwards and downwards (*fig.* 176), it is said to be *fusiform*. The common Radish is a good example.

Again, the term *napiform* is given to a root which is much swollen at its base, so as to assume a somewhat globular form (*fig*. 177), and then tapers below into a long point. It occurs in the common Turnip, and in a variety of the common Radish, which is hence called the Turnip-radish; and in some other plants.

Section 3. The Leaf or Phyllome.

1. GENERAL DESCRIPTION AND PARTS OF THE LEAF.

The leaf may be defined as a lateral development of the stem or branch; it is formed of similar structures, and these are in direct connexion one with the other. The leaf is therefore an appendicular organ of the stem, but it differs from the latter organ in the order of its development; for while in the stem or branch the apex is the youngest part, the reverse is the case in the leaf, where the apex is first formed and consequently the oldest, and is gradually pushed outwards by the formation of the other parts between it and the stem.

The leaves are usually of a green colour and of a more or less flattened nature; but in the Stonecrop, Aloes, and many other plants, they are thick and fleshy, when they are said to be *succulent*. In other cases, as in the scales of the bud, the thin membranous coverings of tunicated bulbs and corms, the fleshy scales of bulbs, and the leaves of Broomrapes, &c., they are colourless, or commonly of a yellowish or brownish colour, and are of simple structure; they are then termed *scales* or *cataphyllary leaves*, the ordinary leaves being called *foliage leaves*.

The part of the stem or branch from which a leaf arises is called a *node*, and the space between two nodes an *internode*. The portion of the leaf nearest to the part from which it arises is termed its *base*, and the opposite extremity the *apex*, and the lines connecting the base and apex the *margins*. The leaf has commonly only two surfaces, but when succulent it has frequently more than two. The terms upper and lower are applied to the two surfaces of ordinary leaves, because in by far the greater number of plants such leaves are placed horizontally, so that one surface is turned upwards, and the other downwards. There are certain leaves, however, which are placed vertically, as those of some species of *Acacia* and *Eucalyptus*, in which case the margins are turned upwards and downwards instead of the surfaces. The angle formed by the union of the upper surface of the leaf with the stem is called the *axil*, and everything which arises out of that point is said to be *axillary* to the leaf; or, if from the stem above, or below the axil, it is *extra-axillary*; or, as more generally described when above, *supra-axillary*, if below, *infra-axillary*.

Leaves commonly fall off after they have performed their functions, but their duration varies in different plants, and they receive different names accordingly. More commonly the leaf lasts throughout the season in which it is developed, when it is *deciduous*; or if beyond a single season, or until new leaves are formed, so that the plant is never without leaves, as in the common Cherry-laurel, it is *persistent*, and the plant is called *evergreen*.

When a leaf separates from the stem, without leaving any trace of its existence, except a scar (*fig.* 139, *b*, *b*) at the point of disruption, as in the Horse-chestnut, it is said to be *articulated*; or if it decays gradually upon it, so that portions remain upon the stem for some time, as in Grasses and Ferns, it is *non-articulated*.

The leaf, in its highest state of development consists of three distinct parts, called respectively *lamina* or *blade*, *petiole* or *leafstalk*, and *stipular portion*. These three parts are by no means always present, although such is frequently the case, as in the Trailing Willow (*fig.* 18); but in numerous plants one of these parts is absent, and in some two, the leaf being in such instances reduced to two or one of its portions only. The petiole and the stipular portion are those which are more commonly absent; in the former case, the leaf is termed *sessile* (*fig.* 188); in the latter, it is *exstipulate* (*fig.* 191). The blade of the leaf is that portion which is not only most commonly present, but it is that which is generally most developed, and performs the more important functions of the leaf; and in ordinary language it is therefore spoken of under the name of leaf. Sometimes the blade is divided into two or more separate parts, when it is called *compound* (*figs.* 249 and 250); or if there is but one blade (*figs.* 206–209), it is said to be *simple.*

2. THE INTERNAL STRUCTURE OF LEAVES.

Leaves with reference to their structure are divided into *aerial* and *submersed*; by the former is to be understood those that are developed and live entirely or partially in the air; by the latter, those that are formed and dwell wholly immersed in water.

1. Aerial Leaves.—In the lowest leaf-bearing plants, such as Mosses, the leaves consist simply of parenchymatous tissue; while in the majority of the higher plants they contain, in addition to this parenchyma, a framework or skeleton formed of wood-cells or liber-cells, or of both, and vessels of different kinds, all of which are in direct connexion with corresponding parts of the fibro-vascular system of the stem or branch. We distinguish, therefore, in such leaves, as in the stem and branch, both a parenchymatous and a fibro-vascular system, the former constituting the soft parts or the *parenchyma* of the leaf; the latter the hard parts, which by their ramification form what are called *veins* or *nerves.*

The *petiole*, when present, consists of fibro-vascular tissue (*fig.* 178), surrounded by parenchyma, and the whole covered by epidermis, which contains but few or no stomata, but is frequently furnished with hairs and other epidermal appendages. The fibro-vascular tissue varies in its nature in the leaves of the different classes of plants, being merely prolongations of that of the three kinds of stems already fully described. Thus in Dicotyledonous plants, the fibro-vascular tissue (*fig.* 178) consists of spiral, and pitted, annular, or some other vessels, and also of laticiferous vessels or sieve-tubes, and wood and liber-cells, that is, of the same elements essentially as the wood and liber—the spiral vessels and the other structures belonging to the xylem being placed above those of the phloëm or liber.

FIG. 178.

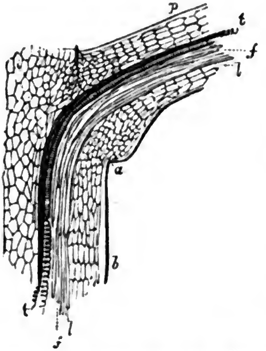


Fig. 178. Fibro-vascular tissue passing from a branch, *b*, of an herbaceous Dicotyledonous plant into the petiole, *p*. *a*. Articulation between the petiole and the branch from which it arises. *t*, *t*. Spiral and annular vessels. *f*, *f*. Wood-cells. *l*, *l*. Liber-cells.

The whole of the *lamina* is covered by the epidermis, which is commonly furnished with stomata in the manner already described. The stomata are, however, almost confined to that portion of the epidermis which corresponds to the parenchyma of the leaf. The epidermis is also frequently furnished with various appendages, as Hairs, Glands, and their several modifications. The epidermis and its appendages having been already fully described under their respective heads, it now remains only to allude to the fibro-vascular and parenchymatous systems of the lamina which are situated between the epidermis of its upper and lower surfaces.

a. *Fibro-vascular System.*—This is in direct connexion with that of the stem or branch in the three great classes of plants respectively. We shall direct our attention more especially to that of the leaves of Dicotyledonous plants. The fibro-vascular system in such plants is in by far the majority of cases *double*, that is, it consists of an upper layer which is in connexion with the fibro-vascular system of the wood and petiole (*fig.* 178, *t*, *f*); and of a lower which is continuous with the liber (*l*). The upper layer therefore corresponds in its structure to the wood, and the lower to the liber; hence the former is composed of spiral and pitted vessels in perennial plants, and of spiral and annular or some other vessels in herbaceous plants, *t*, and also in all cases of wood-cells, *f*, besides the above-named vessels; while the latter consists essentially of liber-cells, *l*, *l*, and

FIG. 179.

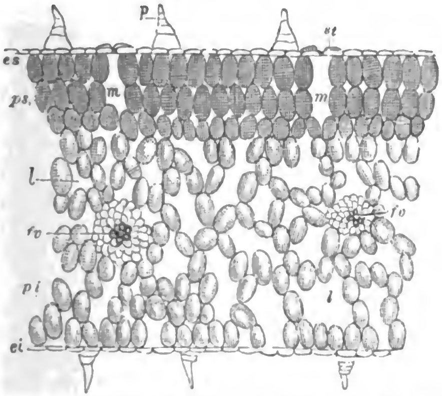


Fig. 179. Vertical section of a portion of the lamina of a leaf of the Melon, highly magnified. *es.* Epidermal tissue of the upper surface, furnished with hairs, *p*, and stomata, *st*. *ei.* Epidermal tissue of the lower surface, with hairs arising from it. *ps.* Three layers of upper parenchymatous cells. *pi.* Parenchymatous cells near to the epidermal tissue of the lower surface. *fv*, *fv*. Fibro-vascular tissue forming the veins. *m*, *m*. Cavities connected with the stomata. *l*, *l*. Cavities between the cells forming spongiform parenchyma.

laticiferous tissue. To whatever extent the fibro-vascular system may branch, each division of the upper layer accurately corresponds at its extremity with a similar division of the lower. This double layer of the fibro-vascular system is readily seen in what are called *skeleton leaves*, namely, those in which the parenchyma between the veins has been destroyed by maceration in water or by other means.

b. *Parenchyma or Mesophyll.*—By this we understand the parenchymatous tissue which is situated between the epidermis of the upper and lower surfaces of the lamina of the leaf (*fig.* 179, *ps*, *pi*), and which surrounds the ramification of the fibro-vascular system or veins, *fv*, *fv*. In ordinary flat leaves all the cells composing the parenchyma are commonly green from containing chlorophyll; but in succulent leaves the cells in the centre of the parenchyma are usually colourless.

The parenchyma also varies in the form and arrangement of its component cells in different parts of the same lamina; thus in ordinary flat leaves we find beneath the epidermis of the upper surface one (*fig.* 180), two, or three layers of closely packed oblong or more or less elongated cells (*fig.* 179, *ps*), placed perpendicularly to the surface, and forming the tissue which has been termed *palisade parenchyma*. In some cases these palisade cells are said not to be single cells, but branches of cells. The form and arrangement of the cells beneath the epidermis, *ei*, of the lower surface are entirely different; thus, here the cells, *pi*, are loosely connected and have numerous large spaces, *l*, *l*, between them; they are also frequently very irregular in form, pre-

FIG. 180.

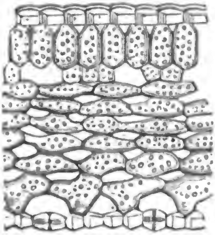


Fig. 180. Vertical section of a leaf of the White Lily highly magnified, showing the epidermis of both the upper and lower surfaces, with the intervening parenchyma.

senting commonly two or more projecting rays (*fig.* 180), which become united with similar projections of the cells next them, and thus leave between them numerous spaces which communicate freely with each other, and form a spongiform parenchyma. These spaces are also connected with the stomata, which, as we have already seen, are generally most abundant on the epidermis of the lower surface, and thus a free communication is kept up between the interior of the blade and the external air, which is essential to the due performance of its functions.

Such is the general arrangement of the parenchyma in the blades of aerial leaves, but it is subject to various modifications in those of different plants. Thus in blades which have their margins turned upwards and downwards instead of their surfaces, the arrangement of the parenchyma is similar beneath the epidermis of both the surfaces; while in succulent leaves the parenchyma is composed of cells which are usually larger than those of ordinary leaves, and closely compacted, or with but few interspaces. In the floating leaves of aquatic plants, again, as the stomata must be placed so as to be in direct communication with the air, they are, as we have seen (page 59), most abundant on the upper surface of the laminæ, and the spongiform parenchyma is then beneath the epidermis of the upper surface, and the compactly arranged cells next that of the under surface, the position of the parts being here completely reversed.

2. Submersed Leaves.—The petiole when present in these leaves is solely formed of parenchymatous cells, which are, however, frequently elongated; and the blades are therefore also necessarily entirely made up of parenchyma, the so-called veins being composed simply of more or less elongated parenchymatous cells. The blades of such leaves are generally very thin, only containing two or three layers of cells, so that all the cells are nearly in contact with the water in which they

are placed The cells are disposed very regularly and have no interspaces, but all contain chlorophyll granules. In submersed leaves, however, which are thickened, we find large cavities which are very regular in their form and arrangement (*fig.* 181, *i*, *i*); these contain air, by which the specific gravity of the leaf is diminished, and it is thus enabled to float in the water. Submersed leaves have no true epidermal layer, and no stomata, both of which would be useless from their being always exposed to similar hygrometric conditions.

FIG. 181.

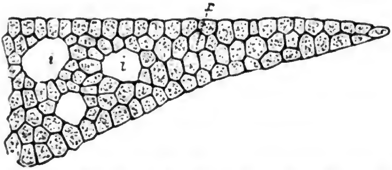


Fig. 181. Vertical section of a leaf of a *Potamogeton*, highly magnified. *i*, *i*. Air cavities. *r*. Parenchymatous cells containing chlorophyll granules.

3. INSERTION AND ARRANGEMENT OF LEAVES.

1. INSERTION.—The point by which a leaf is attached to the stem or branch is called its *insertion*. Leaves are inserted on various parts of the stem and branches, and receive different names accordingly. Thus the first leaves which are developed are called *cotyledons* (*fig.* 14, *c*, *c*) or *nursing leaves*, and those which first succeed them are termed *primordial* (*d*, *d*). Leaves are called *radical* when they arise at, or below, the surface of the ground, and thus apparently from the root, but really from a shortened stem, or *crown of the root* as it is commonly called. The leaves which arise from the main stem are called *cauline*; those from the branches *ramal*; and the modified leaves

arising from the base of, or upon the flower-stalks, are termed *bracts* or *hypsophyllary leaves.*

When a leaf arises from the stem by means of a petiole it is said to be *stalked* or *petiolate* (*fig.* 18, *p*); when the blade of a leaf is fixed to the petiole by a point more or less within its margins, as in the Indian Cress (*fig.* 182), the leaf is termed *peltate*; when the petiole is absent, so that the blade arises directly from the stem, it is said to be *sessile* (*fig.* 188); when a leaf is enlarged at its base and clasps the stem from which it springs it is *amplexicaul* or *embracing* (*fig.* 183), as in Fool's Parsley; or if it forms a complete sheath around it, as in Grasses generally (*fig.* 184), it is said to be *sheathing.* When a leaf is prolonged from its base, so as to form a winged or leafy appendage down the stem, as in Thistles, it is *decurrent* (*fig.* 185); when the two sides of the base of a leaf project beyond the stem and unite, as in the Hare's-ear (*fig.* 186), it is said to be *perfoliate,* because the stem then appears to pass through the blade; or when two leaves placed on opposite sides of the stem unite more or less by their bases, they are said to be *connate,* as in some species of Honeysuckle (*fig.* 187).

FIG. 182.

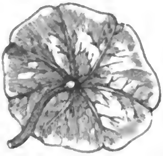


FIG. 183.

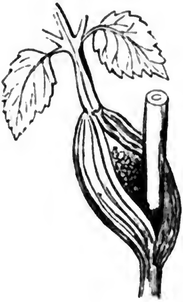


Fig. 182. Peltate leaf of the Indian Cress (*Tropæolum*). —*Fig.* 183. Amplexicaul petiole of *Angelica.*

2. ARRANGEMENT.—The term *phyllotaxis* is used

generally to indicate the various modes in which leaves are arranged on the stem or branch. The following are the more important varieties. Thus, when only one leaf arises from a node, the leaves as they succeed each other are placed alternately on different sides of the stem, and are then said to be *alternate* (*fig.* 191). When two leaves are produced on opposite sides of the stem, they are described as *opposite* (*fig.* 189); or when three or more leaves arise from the stem so as to be arranged around it in the form of a circle, they are called *verticillate* or *whorled* (*fig.* 188), and each circle is termed a *verticil* or *whorl*. When leaves are opposite, the pairs as they succeed each other usually cross at right angles, in which case they are said to *decussate* (*fig.* 189), and the arrangement is called *decussation*. When all the leaves of a branch are

FIG. 184.

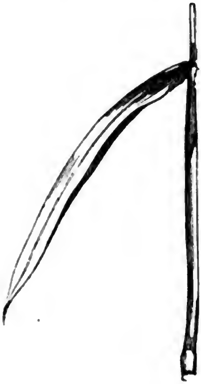


FIG. 185.

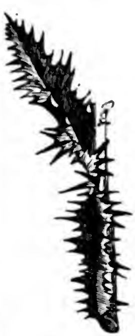


FIG. 186.

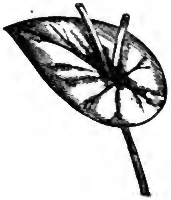


FIG. 187.

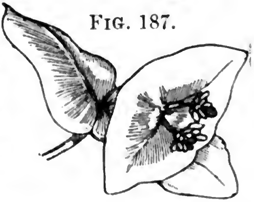


Fig. 184. Sheathing leaf of a Grass.——*Fig.* 185. Decurrent leaf of a species of Thistle.——*Fig.* 186. Perfoliate leaf of a species of Hare's-ear (*Bupleurum rotundifolium*).——*Fig.* 187. Connate leaves of a species of Honeysuckle (*Lonicera Caprifolium*).

brought close together by the non-development of the internodes, they form a *tuft* or *fascicle*, and the leaves are described as *tufted* or *fascicled*, as in the Larch (*fig.* 190).

FIG. 188.

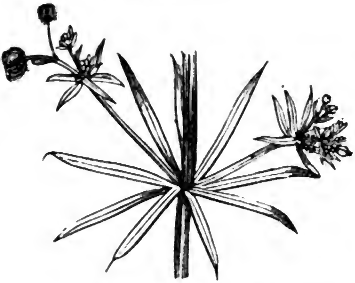


FIG. 189.

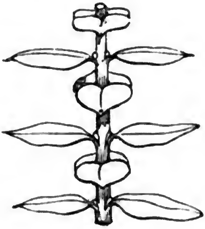


Fig. 188. Whorled leaves of a species of *Galium*.——*Fig.* 189. Decussate leaves of *Pimelea decussata*.

FIG. 190.

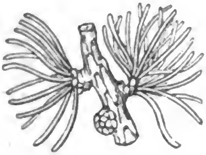


FIG. 191.

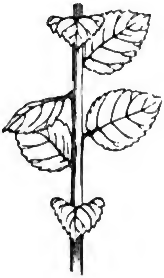


Fig. 190. Fascicled or tufted leaves of the Larch.——*Fig.* 191. A portion of a branch of the Cherry-tree with the leaves alternately arranged.

3. ARRANGEMENT OF THE LEAVES IN THE BUD, OR VERNATION.—Having now described the general arrangement of fully-formed leaves upon the stem or branch, we have in the next place to allude to the different modes in which they are disposed while in a

rudimentary and unexpanded condition in the leaf-bud. To these modifications the general name of *Vernation* or *Præfoliation* has been applied. Under this head we include:—1st, The modes in which each of the leaves considered independently of the others is disposed; and, 2nd, the relation of the several leaves of the same bud taken as a whole to one another. In the *first place* we shall consider the modes in which each of the leaves considered separately is disposed. We arrange these again in two divisions:—1st, Those in which the leaf is simply *bent* or *folded*; and 2nd, Those where it is *rolled*. In the *first division* we have three varieties:—Thus, 1st, the upper half of the leaf may be bent upon the lower, so that the apex approaches the base (*fig.* 192), as in the Tulip tree, it is then said to be *reclinate* or *inflexed*; 2nd, the right half may be folded upon the left, the ends and midrib or axis of the leaf remaining immovable (*fig.* 193), as in the Oak and Magnolia, when it is called *conduplicate*; or, 3rd, each leaf may be folded up a number of times like a fan (*fig.* 194), as in the Sycamore and Vine, when it

FIG. 192.

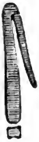


FIG. 193.

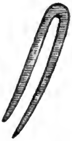


FIG. 194.

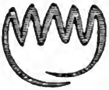


FIG. 195.

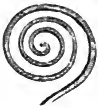


FIG. 196.

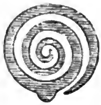


FIG. 197.

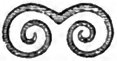


FIG. 198.

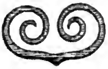


Fig. 192. Vertical section of a reclinate leaf.——*Fig.* 193. Transverse section of a conduplicate leaf.——*Fig.* 194. Transverse section of a plaited or plicate leaf.——*Fig.* 195. Vertical section of a circinate leaf.——*Fig.* 196. Transverse section of a convolute leaf.——*Fig.* 197. Transverse section of a revolute leaf.——*Fig.* 198. Transverse section of an involute leaf.

is *plaited* or *plicate*. Of the *second modification* we have four varieties:—1st, the apex may be rolled up on the axis of the leaf towards the base, like a crosier (*fig.* 195), as in Ferns, when it is *circinate*; 2nd, the whole leaf may be rolled up from one margin into a single coil, with the other margin exterior (*fig.* 196), as in the Apricot and Banana, in which case it is *convolute*; 3rd, the two margins of the leaf may both be rolled inwards on the upper surface of the leaf, towards the midrib, which remains immovable (*fig.* 198), as in the Violet and Water-lily, when it is *involute*; or, 4th, the two margins may be rolled outwards or towards the midrib on the lower surface of the leaf (*fig.* 197), as in the Dock, in which case it is *revolute*.

FIG. 199.

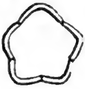


FIG. 200.

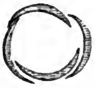


FIG. 201.

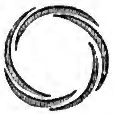


FIG. 202.

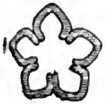


FIG. 203.

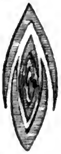


FIG. 204.

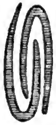


FIG. 205.

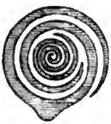


Fig. 199. Transverse section of a bud to show the leaves arranged in a valvate manner.——*Fig.* 200. Transverse section of a bud to show imbricate vernation.——*Fig.* 201. Transverse section of a bud to show twisted or spiral vernation.——*Fig.* 202. Transverse section of a bud to show induplicate vernation.——*Fig.* 203. Transverse section of a bud showing equitant vernation.——*Fig.* 204. Transverse section of a bud showing obvolute vernation.——*Fig.* 205. Transverse section of a bud showing supervolute vernation.

We pass now to consider, *secondly*, the relation of the several leaves of the same bud taken as a whole to one another. Of this we have several varieties which may also be treated of in two divisions:—1st, those in which the component leaves are *flat* or *slightly convex*; and 2nd, where they are *bent* or *rolled*. Of the *first division* we describe three varieties:—1st, that in which the leaves are placed nearly in a circle or at the same level, and in contact by their margins only, without overlapping one another (*fig.* 199), when they are *valvate*; 2nd, that in which the leaves are placed at different levels, and the outer successively overlap the inner to a greater or less extent by their margins (*fig.* 200), as in the Lilac, when they are said to be *imbricate*; and 3rd, if when the leaves are placed as in imbricate vernation, the margin of one leaf overlaps that of another, while it, in its turn is overlapped by a third (*fig.* 201), the vernation is *twisted* or *spiral*. Of the *second division*, viz. where the component leaves of the bud are *bent* or *rolled*, we notice four varieties:—1st, when involute leaves are applied together in a circle without overlapping (*fig.* 202), they are said to be *induplicate*; 2nd, if the leaves are conduplicate, and the outer successively embrace and sit astride of those next within them as if on a saddle (*fig.* 203), as in the leaves of the Iris at their base, they are *equitant*; 3rd, if the half of one conduplicate leaf receives in its fold the half of another folded in the same manner (*fig.* 204), as in the Sage, the vernation is *half-equitant* or *obvolute*; and 4th, when a convolute leaf encloses another which is rolled up in a like manner (*fig.* 205), as in the Apricot, the vernation is *supervolute*.

4. LAMINA OR BLADE.

We have seen that the leaf (*figs.* 18 and 17) in its most highly developed state consists of three parts: namely, of a *lamina* or *blade*, a *petiole* or *stalk*, and of a *stipular* or *vaginal* portion. Each of these portions must now be described in detail, commencing with the *lamina* or *blade*.

VENATION.—The term *venation* or *nervation* is applied generally to indicate the various modes in which the veins, or nerves as they are also called, are distributed throughout the lamina.

In some plants, as Mosses, those living under water, &c., the leaves have no fibro-vascular skeleton, and consequently no true veins, and are hence said to be *veinless*; while in succulent plants the veins are hidden more or less from view, in consequence of the great development of parenchyma, in which case the leaves are termed *hidden-veined*.

In those leaves where the veins are well marked, they are subject to various modifications of arrangement, the more important of which need only be mentioned here. Thus, when there is but one large central vein, proceeding from the base to the apex of the lamina, and from which all the other veins arise, such a vein is called the *midrib* (*fig.* 206); or when there are three or more large veins, which thus proceed from the base to the apex (*fig.* 207) or to the margins (*fig.* 208) of the lamina, the separate veins are then termed *ribs*. The divisions or primary branches of the midrib, or of the separate ribs, are commonly called *veins*; and their smaller ramifications *veinlets*.

There are two marked modifications in the arrangement of the above veins. In the *first modification*, the fibro-vascular tissue as it enters the lamina is either continued as the midrib (*fig.* 206), or it divides into two or more ribs (*figs.* 207 and 208); and from this midrib or ribs other veins are given off; and from them, in like manner, smaller ramifications or veinlets arise, which unite with one another so as to form a kind of network. Or, in the *second modification*, the fibro-vascular tissue is either continued as a midrib from the base to the apex of the lamina, giving off from its sides other veins, which run parallel to the margins, and which are simply connected by unbranched veinlets (*fig.* 213); or it divides at once into several veins or ribs, which proceed from the base to the apex (*fig.* 211) or margins (*fig.* 212) of the blade, more or less

FIG. 206.

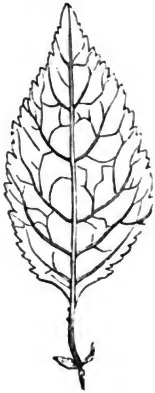


FIG. 208.

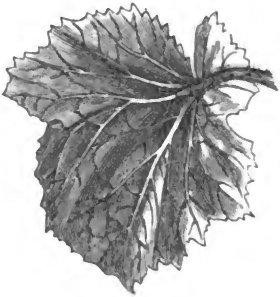


FIG. 209.

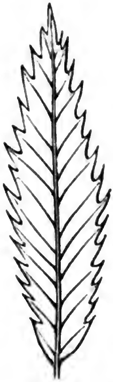


FIG. 207.

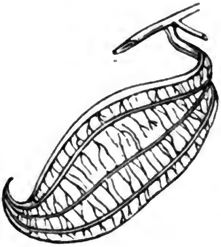


Fig. 206. Leaf of the Cherry with lamina, petiole, and stipules. The lamina has serrate margins, and a large central vein, termed the midrib, is seen to proceed from the petiole to the apex of the leaf, and to give off from its sides the other veins.——*Fig.* 207. Ribbed leaf of Cinnamon with entire margins.——*Fig.* 208. Leaf of the Melon with dentate margins. The venation is radiated or palmately-veined.——*Fig.* 209. Feather-veined leaf of the Spanish Chestnut.

parallel to one another, and are in like manner connected only by simple unbranched veinlets. The leaves which exhibit the first modification are called *reticulated* or *netted-veined* leaves, and occur universally in Dicotyledonous plants; and those which present the second modification are termed *parallel-veined* leaves, and are characteristic with some few exceptions of Monocotyledonous plants.

These two modifications are also subject to certain variations, as follows:—

1. *Varieties of Reticulated or Netted Venation.*

There are two principal varieties of this kind of venation, namely, *feather-veined* or *pinnately-veined*, and the *radiated* or *palmately-veined*. Thus in the first variety the midrib either gives off lateral veins that proceed at once to the margins, and which are connected by numerous branching veinlets, as in the leaves of the Spanish Chestnut (*fig.* 209) and Oak (*fig.* 218); or the midrib gives off branches from its sides, which proceed at first towards the margins, and then curve towards the apex, terminating finally within the margins, with which they are connected by small veins, as in the Dead-nettle (*fig.* 210).

The term *radiated* or *palmately-veined* is applied to a leaf which possesses two or more ribs that arise from at or near the base of the lamina, and diverge from each other towards its margins, and which are connected by branching veins, as in the Melon (*fig.* 208). The *ribbed venation*, as seen in the

FIG. 210.

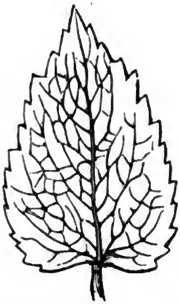


Fig. 210. **Leaf of the Dead-nettle. The venation is netted, and its margins are serrate.**

Cinnamon (*fig.* 207), is but a modification of this variety, in which the ribs, instead of diverging from one another, run in a curved manner from at or near the base of the blade to the apex, towards which they converge; such ribs being connected together by branching veins. If a ribbed leaf has three ribs proceeding from the base, it is said to be *three-ribbed* or *tricostate*; if five, *five-ribbed*; if more than five, *many-ribbed.*

2. *Varieties of Parallel Venation.*

The term parallel-veined is not strictly applicable in all cases, for it frequently happens, as already noticed, that the veins are radiated, but from the difficulty of finding a name which will comprise all the modifications to which such leaves are liable, it must be understood that we apply the term parallel-veined to all leaves in which the main veins of the lamina are more or less parallel, and simply connected by unbranched veinlets.

There are certain characteristic variations of parallel venation. Thus, the main veins may either proceed in a somewhat parallel direction from the base to the apex of the lamina, to which point they converge more or less (*fig.* 211), as in the ordinary ribbed variety of reticulated leaves already noticed, but they are here only connected by unbranched transverse veinlets; or they diverge from one another towards the circumference of the blade (*fig.* 212), as in the radiated-veined variety of reticulated leaves, and are likewise united by cross-veinlets. The leaves of Lilies may be taken as examples of the first variety; and those of many Palms of the second.

Or, the leaves may have a prominent midrib, as in the feather-veined variety of reticulated venation, giving off from its sides along its whole length other veins, which proceed parallel to each other in a straight or curved direction towards, and lose themselves in, the margins (*fig.* 213); and are connected as in the last variety, by unbranched veinlets. The Banana and allied plants furnish us with examples of this variety.

Venation of the Leaves of Acotyledonous Plants.—Besides the above varieties of venation as found in Dicotyledonous and Monocotyledonous plants, the leaves or fronds of Ferns, and those of Acotyledonous plants which possess veins, present us with a third variety; thus, in these the primary venation may be feather-veined or radiated-veined, but the whole of the princi-

FIG. 211.

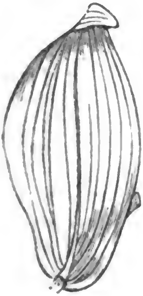


FIG. 212.

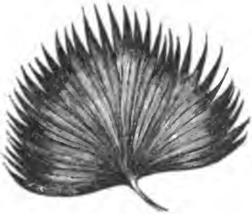


FIG. 213.

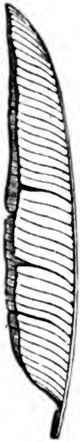


FIG. 214.

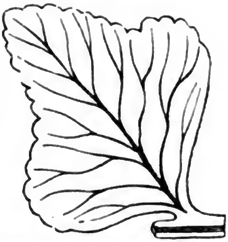


Fig. 211. Leaf showing parallel venation; the margins are entire.——*Fig.* 212. Parallel venation, as seen in the leaf of the Fan Palm (*Chamærops*).——*Fig.* 213. Parallel venation, as seen in the Banana. This form of parallel venation is sometimes distinguished as the *curve-veined*.——*Fig.* 214. Forked venation of a Fern leaf (*frond*); the margins are crenate.

pal veins either divide afterwards in a forked manner (*fig.* 214), or their terminal ramifications are thus divided. Such a variety of venation has therefore been called *forked.*

COMPOSITION.—Leaves are divided into *simple* and *compound.* Thus a leaf is called *simple* if it has only one blade (*fig.* 211), however much this may be divided, so that the divisions do not extend to the midrib (*fig.* 219), or petiole (*fig.* 226); or in some cases the divisions may even extend to the midrib or petiole, but the leaf is still called simple when the parts into which the lamina is divided are attached by a broad base, as in *fig.* 220. (*See* Incision, page 150.) A leaf is termed *compound*, when the petiole divides so as to separate the blade into two or more portions, each of which bears the same relation to the petiole as the petiole itself does to the stem or branch from whence it arises (*fig.* 249). The separated portions of a compound leaf are then called *leaflets* or *folioles*; and these may be either sessile (*fig.* 260), or have stalks (*fig.* 267), each stalk is then termed a *petiolule, stalklet*, or *partial petiole*, and the main axis or stalk which supports them, the *rachis* or *common petiole.*

The leaflets of a compound leaf may be generally at once distinguished from the separate leaves of a branch, from the fact of their being all situated in the same plane; there are, however, to this character, many exceptions. Another mode of distinguishing a simple from a compound leaf arises from the fact that a simple leaf has never more than one articulation, which is placed at the point where it joins the stem; but a compound leaf frequently presents two or more articulations: thus, besides the common articulation to the stem, each of the separate leaflets may be also articulated to the common petiole. (*See* also page 166.) It is, however, frequently the case that many compound leaves only present one articulation, and they can then only be distinguished from those simple leaves which are divided to their midribs or petioles by the greater breadth of attachment of the divisions in the latter instance.

1. SIMPLE LEAVES.—Such leaves present numerous modifications as regards their margins, general outline, form, and other variations of their blades; hence we require a corresponding number of terms to define them, which we shall describe under five heads, as follows:—1. *Margins*; 2. *Incision*; 3. *Apex*; 4. *General Outline*; 5. *Form*.

(1.) *Margins*.—The character of the margins is mainly dependent upon the extent to which the parenchyma is developed between the veins of the lamina. Thus, if the parenchyma completely fills up the interstices between the veins, so that the margins are perfectly even, or free from every kind of irregularity, the leaf is *entire* (*fig*. 211), as in the Orchis tribe. Or, if the parenchyma does not reach the margins, but terminates at a short distance within them, so that the margins are uneven, we distinguish several modifications. Thus, if the margins present sharp indentations like the teeth of a saw, and all point to the apex, the leaf is *serrate* (*fig*. 210), as in the common Deadnettle; or, if similar teeth point towards the base, the leaf is described as *retroserrate*; if these teeth are themselves serrate, it is *biserrate* (*fig*. 215, *b*, and 230), as in the Elm; or when the margins are minutely serrate they are termed *serrulate*. When the teeth are sharp, but do not point in any particular direction, and are separated by concavities, the leaf is *dentate* or *toothed*

FIG. 215.

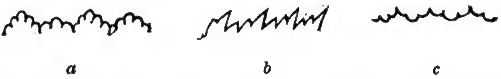


Fig. 215. Diagram of the margins of leaves. *a*. Bicrenate. *b*. Biserrate. *c*. Duplicato-dentate.

(*figs.* 208 and 236), as in the Melon; or when the teeth are themselves divided in a similar manner, it is *duplicato-dentate* (*fig.* 215, *c*). When the teeth are rounded (*fig.* 214) the leaf is *crenate*, as in Horseradish; or if these teeth are themselves crenate it is *bicrenate* (*fig.* 215, *a*); or when the leaf is minutely crenate it is said to be *crenulated*. When the margins are slightly sinuous or wavy, as in the Holly (*fig.* 217), they are said to be *wavy* or *undulated*; or when the margins are very irregular, being twisted and curled, as in the Garden Endive, they are called *crisped* or *curled* (*fig.* 216).

FIG. 216.

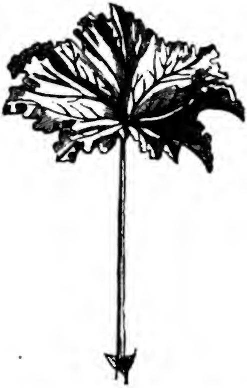


FIG. 217.

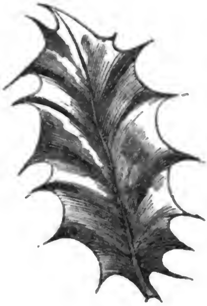


Fig. 216. Crisped or curled leaf of a species of Mallow (*Malva*).——*Fig.* 217. Spiny leaf of Holly (*Ilex Aquifolium*), with wavy margins.

(2.) *Incision.*—This term is employed when the margins of the blades are more deeply divided than in the above instances, so that the parenchyma only extends about midway or a less distance between them and the midrib or petiole. The divisions are then commonly called *lobes*. It is usual, however, to give different names to these divisions, according to the depth of the incisions by which they are produced; thus if they reach to about midway between the margins and midrib (*fig.* 218) or petiole (*fig.* 225), they are properly called *lobes*, and the intervals between them *fissures*, or in composition the term *-fid* is used; if nearly to the base or midrib (*fig.* 219), they are termed *partitions*, and the leaf is *partite*; if quite down to the base or midrib, they are called *segments* (*fig.* 220), and the leaf is *dissected*, or in composition *-sected*. The segments of the latter differ from the leaflets of compound leaves in not being articulated; and also in being united to the midrib or petiole by a broad base.

FIG. 218.

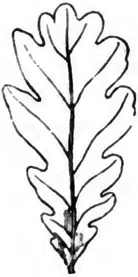


FIG. 219.

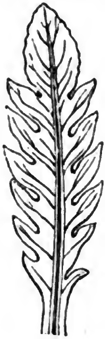


FIG. 220.

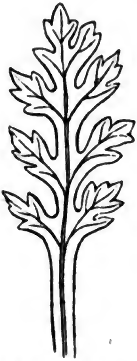


Fig. 218. Feather-veined leaf of the Oak. Its lobes are arranged in a pinnatifid manner.——*Fig.* 219. Pinnatipartite leaf of a species of Valerian (*Valeriana dioica*).——*Fig.* 220. Pinnatisected leaf of a species of Poppy (*Papaver Argemone*).

In describing the above incised leaves we say that they are *bifid* or *two-lobed*, *trifid* or *three-lobed*, &c., according to the number of their fissures or lobes; or *bipartite*, *tripartite*, *bisected*, *trisected*, &c., according to the number of partitions or segments. Or, as the divisions of the lamina are always arranged in the direction of the principal veins, instead of using terms indicating the number of lobes, partitions, or segments, others are generally employed that define the leaf more accurately, which are derived from the mode of venation combined with that of incision. Thus, if the lamina is feather-veined, and the divisions consequently arranged in that manner, the leaf is said to be *pinnatifid* (*fig.* 218), *pinnatipartite* (*fig.* 219), or *pinnatisected* (*fig.* 220), according to their depth, as already described. In some leaves the divisions are themselves incised in a similar manner, and the leaf is then said to be *bipinnatifid*, *bipinnatipartite*, or *bipinnatisected*. Or, if the subdivisions of these are again divided in a similar manner, *tripinnatifid*, *tripinnatipartite*, or *tripinnatisected*. Or, when

FIG. 221.

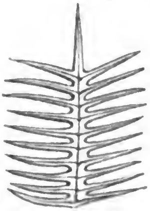


FIG. 222.

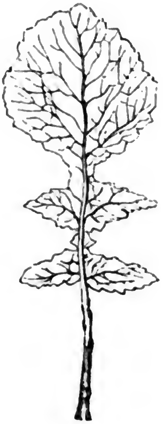


FIG. 223.

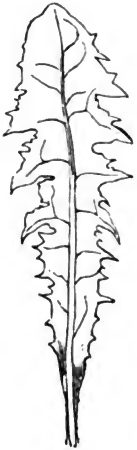


FIG. 224.

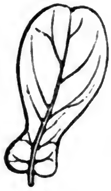


Fig. 221. Pectinate or comb-shaped leaf.——*Fig.* 222. Lyrate leaf of the common Turnip (*Brassica Rapa*).——*Fig.* 223. Runcinate leaf of Dandelion (*Taraxacum officinale*).——*Fig.* 224. Fiddle-shaped leaf of *Rumex pulcher*.

the lamina is still further divided, the leaf is said to be *decomposed* or *laciniated.*

Certain modifications of these varieties have also received special names; thus, when a pinnately-veined leaf is deeply divided, and the divisions are very close and narrow like the teeth of a comb (*fig.* 221), it is said to be *pectinate*, as in the Water Milfoil; when the terminal lobe of a pinnately-veined leaf is large and rounded, and the lateral lobes gradually smaller towards the base, it is *lyrate* or *lyre-shaped* (*fig.* 222); when the terminal lobe is triangular, and the other lobes which are also more or less of the same shape have their points directed downwards towards the base of the lamina (*fig.* 223), the leaf is said to be *runcinate*; or when a lyrate leaf has but one deep recess on each side, so that it resembles a violin in shape, it is termed *panduriform* or *fiddle-shaped* (*fig.* 224).

The above terms are those which are employed to define incised feather-veined leaves; but when the blades are palmately-veined and incised, other terms are used according to the degree of division. In describing such leaves, the terms *bifid*, *trifid*, &c., *bipartite*, *tripartite*, &c., *bisected*, *trisected*, &c., are employed according to the number of their lobes, partitions, or segments, as already noticed; or the terms *palmatifid*, *palmatipartite*, *palmatisected*, derived from the direction of the veins, combined with that of incision, are used. Special names are also applied to certain modifications of these palmately-veined leaves as with those which are pinnately-veined. Thus, when the blade of such a leaf has five spreading lobes united at their base by a more or less broad expansion of parenchyma, so that the whole has a resemblance to the palm of the hand with spreading fingers, the leaf is termed *palmate* (*fig.* 225); or when there are more than five lobes, the leaf is properly described as *palmatifid* or *palmately-cleft* (*fig.* 226). The terms palmate and palmatifid are, however, sometimes used indifferently by authors, to indicate either modification. When the lobes are less spreading, narrower, and somewhat deeper than in a true palmate leaf, the leaf is sometimes termed *digitate*; or when there are more than five lobes of a similar character, as in the Bitter Cassava, it may be termed *digitipartite*. When the lamina is divided nearly to its base into numerous narrow thread-like divisions, as in the submersed leaves of the Water Crowfoot, the leaf is said to be *dissected*. When the lateral lobes, partitions, or segments, of what would otherwise be a palmate leaf are themselves divided into two or more divisions (*fig.* 227), as in the Stinking Hellebore, so that the whole bears some resemblance to a bird's foot, the leaf is termed *pedatifid*, *pedatipartite*, or *pedatisected*, according to the depth of the divisions.

FIG. 225.

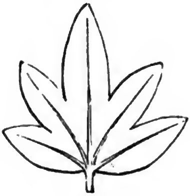


FIG. 226.

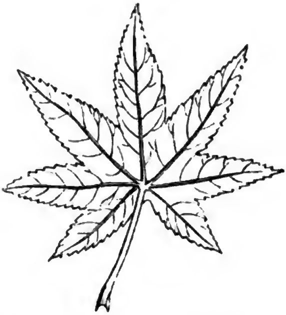


Fig. 225. Palmate leaf of a species of Passionflower (*Passiflora*).—— *Fig.* 226. Palmatifid leaf of the Castor-oil Plant (*Ricinus communis*).

Besides the above modifications of palmately-veined leaves, other variations also occur, in consequence of the lobes, partitions, or segments of the lamina becoming themselves divided, either in a pinnately-veined or palmately-veined manner, and terms are used accordingly, the application of which will be at once evident from what has been already stated.

(3.) *Apex.*—This varies much in different leaves. Thus the apex is *obtuse* or *blunt*, when it is rounded (*fig.* 237), as in the Primrose; it is *retuse* when it is obtuse, with a broad shallow notch in the middle, as in the leaflets of Logwood; or when under the same circumstances the notch is sharp, or somewhat triangular, it is *emarginate* (*fig.* 228), as in the common Box. When the lamina terminates very abruptly, as if it had been cut across in a straight line, the apex is

FIG. 227.

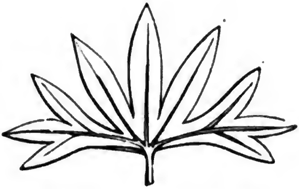


Fig. 227. **Pedatipartite leaf.**

FIG. 228.

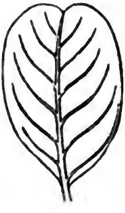


FIG. 229.

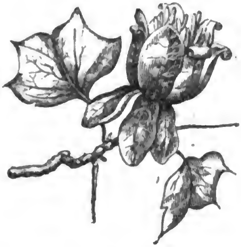


Fig. 228. **Leaflet of a species of *Cassia*. It is obovate in figure or outline, oblique at the base, and emarginate at its apex.**——*Fig.* **229. Branch of Tulip-tree (*Liriodendron tulipifera*) with flower and leaves. The latter terminate abruptly; hence they are said to be *truncate*.**

truncate, as in the leaf of the Tulip-tree (*fig.* 229); or if under the same circumstances the termination is ragged and irregular, as if it had been bitten off, it is *præmorse*, as in the leaf of *Caryota urens.* When the apex is sharp, so that the two margins form an acute angle with each other (*fig.* 231), it is *acute* or *sharp-*

FIG. 230.

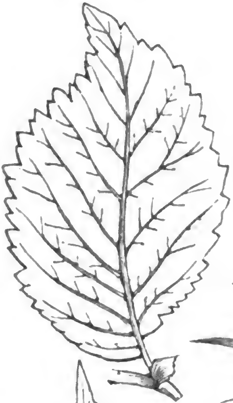


FIG. 231.

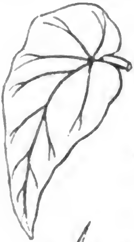


FIG. 232.

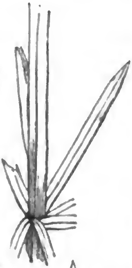


FIG. 233.

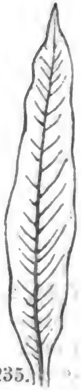


FIG. 234.

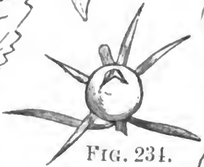
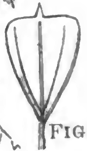


FIG. 235.



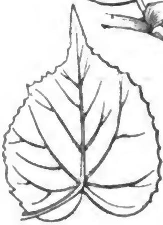


FIG. 236.

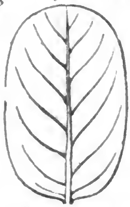


FIG. 237.

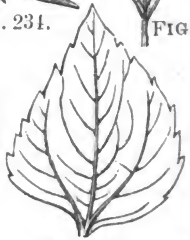


FIG. 238.

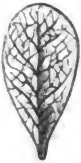


FIG. 239.

Fig. 230. Leaf of Elm, with its margins biserrate, and the lamina unequal at its base.——*Fig.* 231. Unequal or oblique leaf of a species of *Begonia.*——*Fig.* 232. Linear leaf of Goose-grass (*Galium Aparine*).——*Fig.* 233. Lanceolate leaf.——*Fig.* 234. Acerose or needle-shaped leaves of Juniper (*Juniperus communis*).——*Fig.* 235. A cuneate and mucronate-pointed leaf.——*Fig.* 236. Cordate and acuminate leaf, with its margins dentate.——*Fig.* 237. Oblong leaf of Bladder-Senna (*Colutea arborescens*).——*Fig.* 238. Ovate leaf, with its margins serrate.——*Fig.* 239. Obovate leaf.

pointed; when the point is very long, and tapering (*fig.* 236), it is *acuminate* or *taper-pointed*; or when it tapers gradually into a rigid point, it is *cuspidate*, as in many *Rubi*. When the apex, which is then commonly rounded, has a short hard or softened point standing on it, it is *mucronate* (*fig.* 235), as in the leaf of *Lathyrus pratensis*.

(4.) *General Outline or Figure.*—By the general outline or shape of the lamina we mean the superficial aspect or figure which is described by its margins. The development of veins and parenchyma is usually nearly equal on the two sides of the midrib or petiole, so that the lamina of the leaf is in most instances nearly symmetrical and of some regular figure; in which case the leaf is said to be *equal* (*figs.* 236–238). When, as occasionally happens, the lamina of the leaf is more developed on one side than on the other, the leaf is termed *unequal* or *oblique* (*fig.* 230); this is remarkably the case in the species of *Begonia* (*fig.* 231).

When the lamina of a leaf is nearly of the same breadth at the base as near the apex, narrow, and with the two margins parallel (*fig.* 232), the leaf is called *linear*, as in most Grasses; when a linear leaf terminates in a sharp rigid point like a needle, as in the common Juniper (*fig.* 234), and many of our Firs, it is *acerose* or *needle-shaped*. When the blade of a leaf is very narrow, and tapers from the base to a very fine point, so that it resembles an awl in shape, as in the common Furze, the leaf is *subulate* or *awl-shaped*. When the blade of a leaf is broadest at the centre, three or more times as long as broad, and tapers perceptibly from the centre to both base and apex, as in the White Willow, the leaf is *lanceolate* (*fig.* 233); when it is longer than broad, of about the same breadth at its base and apex, and slightly acute at these points, it is *oval* or *elliptical* (*fig.* 241), as in the Lily-of-the-Valley; or if under the same circumstances it is obtuse or rounded at each end (*fig.* 237), it is *oblong*. By many botanists, however, the term oval is applied to a leaf the lamina of which is only two to three times—and oblong, to one which is four or more times, as long as broad; and in both cases either rounded or acute at the two extremities. If the lamina of a leaf is more or less rounded at the base and broader at this part than at the apex, so that the whole is of the shape of an egg cut lengthwise, the leaf is *ovate* or *egg-shaped* (*fig.* 238), as in the Lilac; or, if of the same figure, but with the apex broader than the base (*fig.* 239), it is *obovate* or *inversely egg-shaped*. When the lamina is broad at the apex, and abrupt-pointed, and tapers towards the base (*fig.* 235), as in some Saxifrages, the leaf is *cuneate* or *wedge-shaped*; or if the apex is broad and rounded, and tapers down to the base (*fig.* 240), it is *spathulate*, as in the Daisy. When the lamina is broad and hollowed out at its base into two rounded lobes, and more or less pointed at the apex, so that it somewhat resembles in shape the heart

FIG. 240.

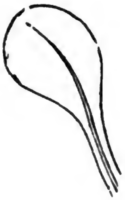


FIG. 241.

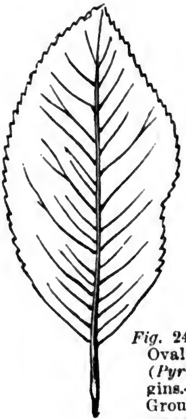


FIG. 242.

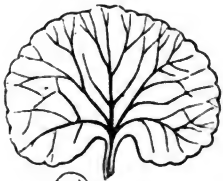


FIG. 243.

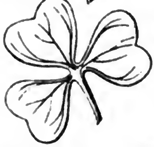


Fig. 240. Spathulate leaf.——*Fig.* 241. Oval or elliptical leaf of Pear tree (*Pyrus communis*), with serrate margins.——*Fig.* 242. Reniform leaf of Ground Ivy (*Nepeta Glechoma*), with crenate margins.——*Fig.* 243. Trifoliate leaf with obcordate leaflets.

in a pack of cards, the leaf is *cordate* or *heart-shaped* (*fig.* 236), as in the Black Bryony; or if of the same shape, but with the apex broader than the base, and hollowed out into two rounded lobes, it is *obcordate* or *inversely heart-shaped* (*fig.* 243). When a leaf resembles a cordate one generally in shape, but with its apex rounded, and the whole blade usually shorter, and broader (*fig.* 242), it is *reniform* or *kidney-shaped*, as in the Asarabacca (*Asarum europæum*). When the blade is broad and hollowed out at its base into two acute lobes, and pointed at the apex, so that it resembles the head of an arrow (*fig.* 244), the leaf is *sagittate* or *arrow-shaped*, as in the Arrowhead; when the lobes of such a leaf are placed horizontally, instead of passing downwards, it is *hastate* or *halbert-shaped* (*fig.* 245), as in Sheep's Sorrel; or when the lobes of such a leaf are separated from the blade, as in the upper leaves of the Woody Nightshade, it is *auriculate* or *hastate-auricled* (*fig.* 246). When the blade is perfectly round, the leaf is *orbicular* (*fig.* 248), a figure which is scarcely or ever found; but when it approaches to orbicular, as in *Pyrola rotundifolia*, the leaf is *subrotund* or *rounded* (*fig.* 247).

It frequently happens that a leaf does not distinctly present any of the above-described figures, but exhibits a combination of two of them, in which case we use such terms as *ovate-lanceolate*, *linear-lanceolate*, *cordate-ovate*, *cordate-lanceolate*, *elliptico-lanceolate*, *roundish-ovate*, &c., the application of which will be at once evident.

In many cases we find leaves of different figures on the same plant; under which circumstance the plant is said to be *heterophyllous*. Thus, in the Harebell, the radical leaves are *cordate* or *reniform*, and the cauline leaves *linear*; and this difference of figure between the radical and stem leaves is by no means uncommon. In water plants again, where some of the leaves are submersed, while others float on the water, or rise above it into the air, as in the Water Crowfoot, the

FIG. 244.

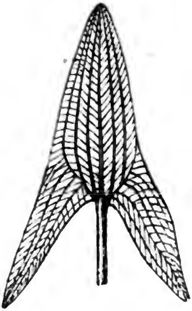


FIG. 246.

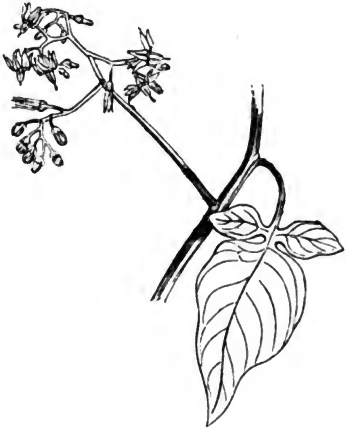


FIG. 245.

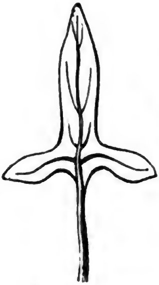


FIG. 247.

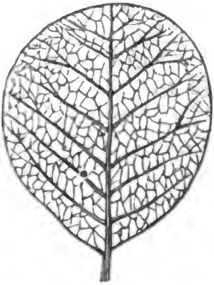


FIG. 248.

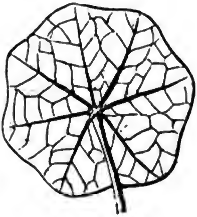


Fig. 244. Sagittate leaf.——*Fig.* 245. Hastate leaf.——*Fig.* 246. A portion of the stem of the Woody Nightshade (*Solanum Dulcamara*), bearing flowering stalk and an auriculate leaf.——*Fig.* 247. A sub-rotund or rounded leaf, with entire margins.——*Fig.* 248. Orbicular peltate leaf.

leaves thus differently situated frequently vary in shape.

(5.) *Form.*—By this term we understand the solid configuration of the lamina—that is, including its length, breadth, and thickness. The terms used in defining the various forms are therefore especially applicable to succulent leaves. Such leaves either assume some regular geometrical form, and are described as *cylindrical*, *pyramidal*, *conical*, &c.; or they approach in form to some well-known objects, and are hence termed *acicular*, *ensiform*, *clavate*, *linguiform*, &c. Or, in other instances, the lamina is more or less hollowed out in its centre, when the leaf is said to be *tubular*, *hooded*, &c.

FIG. 249.

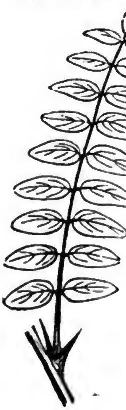


FIG. 250.

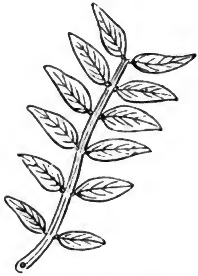


Fig. 249. Imparipinnate or unequally pinnate leaf of *Robinia*, with spiny stipules.——*Fig.* 250. Equally or abruptly pinnate leaf.

2. COMPOUND LEAVES.—The separate leaflets are subject to similar modifications of their margins, incision, apex, outline, and form, as the blades of simple leaves, and the same terms are accordingly used in describing them. We have therefore only now to speak of their special modifications, which we shall do under two heads, namely: 1. *Pinnately* or *feather-veined Compound Leaves*; and 2. *Palmately* or *radiated-veined Compound Leaves*.

(1.) *Pinnately-veined Compound Leaves.*—When a leaf presenting this kind of venation is separated into distinct portions or leaflets, it is termed *pinnate* (*figs.*

FIG. 251.

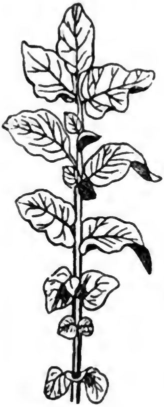


FIG. 252.

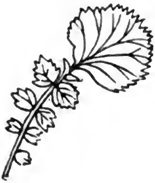


FIG. 253.

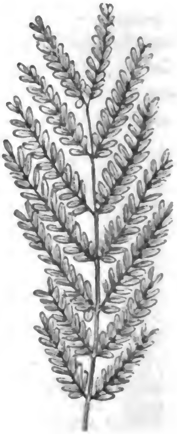


FIG. 254.

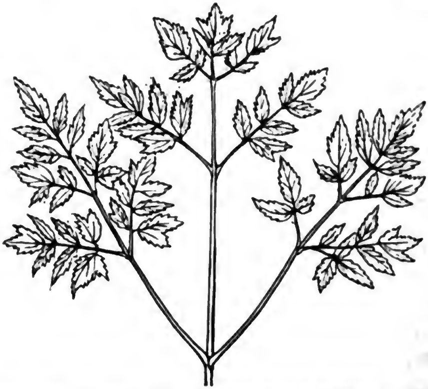


Fig. 251. Interruptedly pinnate leaf of the Potato.——*Fig.* 252. Lyrately pinnate leaf.——*Fig.* 253. Bipinnate leaf of a species of *Gleditschia.*——*Fig.* 254. A tripinnate leaf. Some of the leaflets are, however, only bipinnate.

249–252); and the leaflets are then termed *pinnæ*. The leaflets are arranged either in an opposite or alternate manner along the sides of the common petiole in pairs, and according to their number the leaf is said to be *unijugate* or *one-paired*, *bijugate* or *two-paired*, *trijugate* or *three-paired*, and *multijugate* or *many-paired* (*fig.* 249). Several kinds of pinnate leaves have also been distinguished by special names. Thus when a pinnate leaf ends in a single leaflet (*fig.* 249), as in the Rose, it is *imparipinnate* or *unequally-pinnate*, or *pinnate with an odd leaflet*; it is *equally* or *abruptly pinnate*, or *paripinnate*, when it ends in a pair of leaflets or pinnæ (*fig.* 250), as in *Orobus tuberosus*; and it is *interruptedly pinnate* (*fig.* 251) when the leaflets are of different sizes, so that small pinnæ are regularly or irregularly intermixed with larger ones, as in the Potato. Or, when the terminal leaflet of a pinnate leaf is the largest, and the rest gradually smaller as they approach the base (*fig.* 252), it is *lyrately pinnate*, as in the common Turnip.

When the leaflets of a pinnate leaf become themselves pinnate, or, in other words, when the partial petioles which are arranged on the common petiole exhibit the characters of an ordinary pinnate leaf, it is said to be *bipinnate* (*fig.* 253); the leaflets borne by the partial or secondary petioles are then commonly termed *pinnules*. When the pinnules of a bipinnate leaf become themselves pinnate, it is *tripinnate* (*fig.* 254), as in the Meadow Rue; or if the division extends beyond this, the leaf is *decompound*, as in many Umbelliferous plants.

(2.) *Palmately-veined Compound Leaves.*—Such a leaf is formed when the ribs of a palmately-veined leaf bear separate leaflets, and hence these leaves are readily distinguished from those of the pinnate kind, by their leaflets coming off from the same point, instead of, as in them, along the sides of a common petiole. We distinguish several kinds of such leaves; thus, a leaf is said to be *binate* or *bifoliate*, if it consists of only two leaflets springing from a common point (*fig.* 255), as in *Zygophyllum*; it is *ternate* or *trifoliate* if it consists of three leaflets arranged in a similar manner (*figs.* 256), as in the genus *Trifolium*; it is *quadrinate* or *quadrifoliate* if there are four leaflets (*fig.* 257), as in Herb Paris; it is *quinate* or *quinquefoliate* if there are five (*fig.* 258), as in *Potentilla alba*; it is *septenate* or *septemfoliate*, if there are seven (*fig.* 259); and it is *multifoliate* if there are more than seven (*fig.* 260), as in the Lupin. In speaking of palmately-veined compound leaves in a general sense, they are commonly,

FIG. 255.

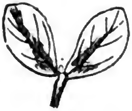


FIG. 256.

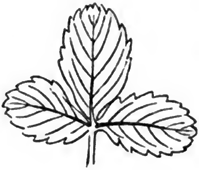


FIG. 257.

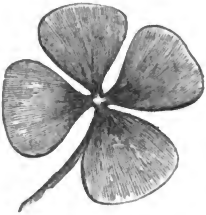


Fig. 255. A binate leaf.——*Fig.* 256. Ternate or trifoliate leaf.——*Fig.* 257. Quadrifoliate leaf of *Marsilea quadrifolia.*

FIG. 258.

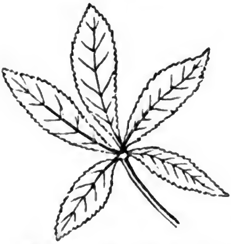


FIG. 259.

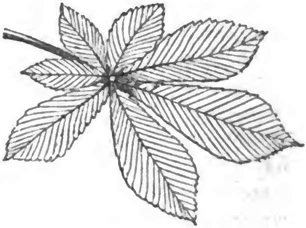


Fig. 258. Quinate or quinquefoliate leaf.——*Fig.* 259. Septenate leaf of the Horsechestnut (*Æsculus Hippocastanum*).

although improperly, termed *palmate* or *digitate*; but when the leaflets of a palmately-veined leaf are arranged in a pedate manner, the leaf is properly termed *pedate*. (See page 154.)

Palmately-veined compound leaves may become still more divided. Thus, if the common petiole divides at its apex into three partial ones, each of which bears three leaflets (*fig.* 261), as in the Masterwort, the leaf is termed *biternate*; or when the common petiole divides at its apex into three partial ones, and these again divide into three others, each of which bears three leaflets, as in the Baneberry, the leaf is *triternate*; or when such a leaf is still further divided, it is said to be *decompound*.

FIG. 260.

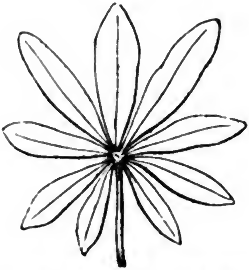


FIG. 261.

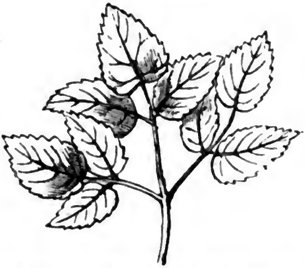


Fig. 260. Multifoliate leaf of a Lupin.——*Fig.* 261. A biternate leaf.

5. PETIOLE OR LEAF-STALK.

The petiole is that part which connects the blade of the leaf with the stem or branch (*fig.* 18, *p*). It consists, as already described (page 132), of fibro-vascular tissue (*fig.* 262, *fv*), surrounded by parenchyma, *pc*; and the whole covered by epidermis, which contains few or no stomata, but is frequently furnished with hairs and other epidermal appendages.

The petiole is either *simple* or undivided, as in all simple leaves, and in those of a compound character in which the leaflets are sessile (*fig.* 260); or it is *compound*, as in the Rose, when it divides into two or more portions, each of which bears a leaflet (*fig.* 267). The branches of the petiole or the stalks of the leaflets are then called *petiolules*, *stalklets*, or *partial petioles*; while the main petiole is termed the *rachis* or *common petiole*.

The petiole is frequently more or less contracted at the base where it joins the stem owing to the presence of an *articulation* or *joint* (*fig.* 262, *f*). Leaves thus furnished with an articulated petiole fall away from the stem after they have performed their functions; and in doing so they leave a *scar* or *cicatrix* (*fig.* 139, *b*, *b*).

The presence of an articulation is to some extent a character of distinction between the three great classes of plants. Thus the leaves of Dicotyledons are in the majority of instances articulated; while those of Monocotyledons and Acotyledons are usually non-articulated. Hence the leaves of the two latter classes, when they have performed their functions, instead of falling away and leaving a cicatrix as the former, decay gradually upon their respective plants, to the stems and branches of which they thus give a ragged appearance. There are many instances, however, in which the leaves of Dicotyledonous plants are not articulated, as in the Oak, in which cases the leaves, although dead, remain attached to their respective plants frequently for months.

On the lower surface of the petiole at its base, the parenchyma frequently forms a slight swelling (*figs.* 262, *c*, and 263), to which the name of *pulvinus* has been given. A somewhat similar swelling may be also seen in many compound leaves at the base of each partial petiole; each of which is then termed a *struma*. The pinnate leaves of the Sensitive Plant afford a good illustration of the presence of both pulvinus and strumæ.

Forms of the Petiole.—The form of the petiole varies in different leaves. It is usually rounded below, and flattened or more or less grooved above; but in other cases it is cylindrical, especially in the leaves of Monocotyledonous plants; while in other plants of the same class, especially in Grasses, it becomes widened at its base, and surrounds the stem in the form of a *sheath* or *vagina* (*fig.* 264, *g*). This sheath in all true Grasses terminates above in a membranous appendage (*fig.* 264, *lig*), which is entire, or divided into two symmetrical portions, or incised in various ways; to this the

FIG. 262.

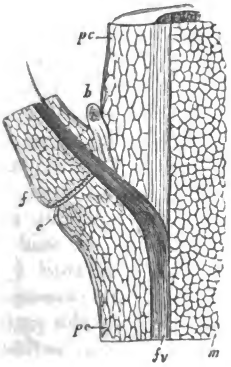


FIG. 263.

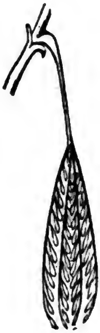


FIG. 264.

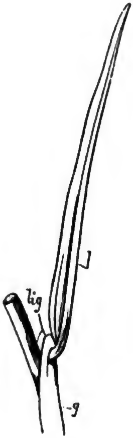


Fig. 262. Vertical section of a portion of the stem and the base of a leaf, showing the passage of the fibro-vascular tissue, *fv*, into the petiole. *pc*, *pc*. Parenchymatous tissue of the stem and petiole. *c*. Pulvinus. *f*. Articulation between the leaf and stem. *b*. Leaf-bud in the axil of the petiole. *m*. Pith.——*Fig.* 263. A portion of a branch and leaf of the Sensitive Plant, showing pulvinus at the base of the petiole.——*Fig.* 264. Stem of a Grass with a leaf attached. *l*. Blade. *g*. Sheathing petiole. *lig*. Ligule.

name of *ligule* has been given, and is now supposed by most authorities to be analogous to the stipules. In the Aspen, the petiole is flattened in a line at right angles to the blade, while in other plants it is flattened in a horizontal direction. In some water plants the petiole is frequently more or less dilated from the presence of a number of air cavities, as in *Pontederia*; hence such petioles by diminishing the specific gravity of the plants enable them to float readily in the water. At other times the petiole becomes enlarged at its base, and embraces the stem, in which case the leaf is said to be *amplexicaul* (*fig.* 183); this commonly occurs in Umbelliferous plants. Frequently the petiole presents at its two edges a leaf-like border, called a *wing*, when it is said to be *winged*, as in Venus's Flytrap (*fig.* 265, *p*), and many other plants. Other still more remarkable forms also occur, which will be alluded to under the head of Anomalous Forms of Leaves.

FIG. 265.

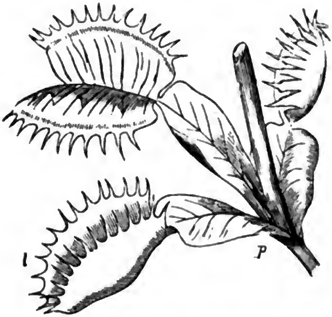


Fig. 265. A portion of the stem with some leaves of Venus's Flytrap (*Dionæa muscipula*). *l*. Lamina fringed with hairs, and hence said to be ciliated. *p*. Winged petiole.

6. STIPULES.

Stipules are small leafy bodies situated at the base, and usually on each side of the petiole of simple (*fig.* 18, *s*, *s*) or compound (*fig.* 266) leaves. They have the same structure as the blades of leaves, and are liable to similar modifications as regards their duration, venation, apex, incision, outline, margins, &c., which variations are therefore described by corresponding names. The stipules are often wanting, and the leaves are then said to be *exstipulate*; when present, the leaves are *stipulate*. In some plants the leaflets of a compound leaf possess little stipules of their own, as in the Bean; these then are called *stipels*, and the leaf is termed *stipellate*.

The stipules vary in their position with regard to the petiole and to each other, and have received different names accordingly. Thus, when they adhere to each side of the base of the petiole, as in the Rose (*fig*. 267, *s*, *s*), they are said to be *adnate* or *adherent*. When they remain as little leafy expansions on each side of the base of the petiole, but quite distinct from it, as in the Pansy (*fig*. 268), they are called *caulinary*. When the stipules are large, it sometimes happens that they meet on the opposite side of the stem or branch from which the leaf grows, and become united more or less by their outer margins, and thus form one stipule, as in the *Astragalus*, they are then said to be *opposite* (*fig*. 269, *s*); if under similar circumstances they cohere by their

FIG. 266.

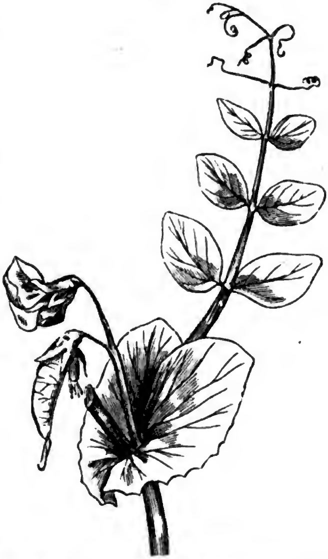


Fig. 266. A portion of the flowering stem of the common Pea, with a pinnate leaf terminated by a tendril, and having two large stipules at its base, the lower margins of which are dentate.

inner margins (*fig.* 270, *s*), they form a solitary stipule which then is placed in the axil of the leaf, and is accordingly termed *axillary*; if such stipules cohere by both outer and inner margins so as to form a sheath which encircles the stem above the leaf (*fig.* 17, *d*), as in most plants of the order Polygonaceæ, they form what is termed an *ochrea*.

FIG. 267.

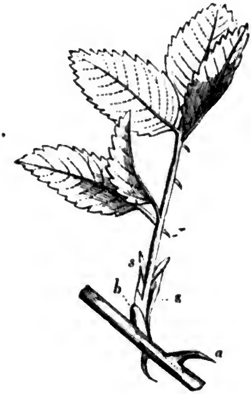


FIG. 268.

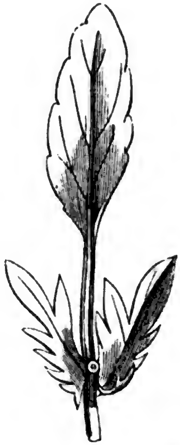


Fig. 267. A portion of a branch of the common Rose (*Rosa canina*). *a*. A prickle. *b*. Bud in the axil of a compound leaf, with stalked leaflets. *s*, *s*. Adnate or adherent stipules.——*Fig.* 268. Leaf of Pansy (*Viola tricolor*) with large caulinary stipules at its base.

All the above kinds of stipules occur in plants with alternate leaves, in which such appendages are far more common than in those with opposite leaves. When the latter plants have stipules these are generally situated in the intervals between the petioles on each side, and are hence termed *interpetiolar* (*fig.* 271, *s*).

Stipules are very rare in Monocotyledons, except the ligule of Grasses be considered as analogous to them, as most botanists now regard it. The only orders of Monocotyledons in which otherwise they undoubtedly occur are the Naiadaceæ and Araceæ. They are altogether absent in Acotyledonous plants.

FIG. 269.

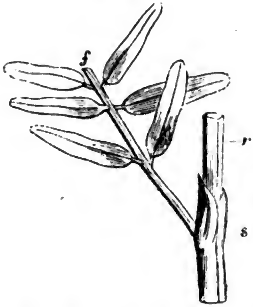


FIG. 270.

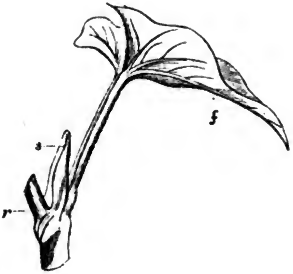


Fig. 269. A portion of the stem, *r*, and leaf, *f*, of *Astragalus Onobrychis*. *s*. Synochreate or opposite stipule.——*Fig.* 270. A portion of the stem, *r*, and leaf, *f*, of *Houttuynia cordata*. *s*. Axillary stipule.

FIG. 271.

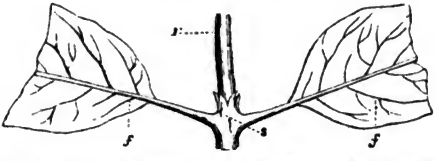


Fig. 271. A portion of a branch, *r*, with two opposite leaves, *f*, *f*, of *Cephalanthus occidentalis*. *s*. Interpetiolar stipule.

7. ANOMALOUS FORMS OF LEAVES.

We have already seen that the branches of a stem sometimes acquire an irregular development, and take the form of Spines or Tendrils. (See pages 102 and 103.) In the same manner the parts of a leaf may assume similar modifications, as well as some others still more remarkable, which we now proceed to describe.

Spines of Leaves.—Any part of the leaf may exhibit a spiny character. Thus,—1st, the veins may project beyond the blade, as in the Holly (*fig.* 217), and become hard and spiny; while in the Barberry the blade has little or no parenchyma produced between its veins, which are of a spiny character, so that the whole lamina becomes spinous. 2nd. The petiole may assume a spiny character, either at its apex, as in some species of *Astragalus*; or at its base from the pulvinus, as in the Gooseberry. And, 3rd. The stipules may become transformed into spines, as in *Robinia pseud-acacia* (*fig.* 249).

FIG. 273. FIG. 274.

FIG. 272.

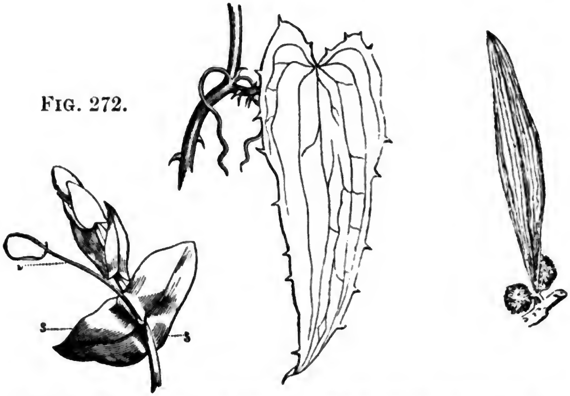


Fig. 272. A portion of the stem of *Lathyrus Aphaca*, with stipules, *s*, *s*, and cirrhose petiole, *r*.——*Fig.* 273. A portion of the stem of *Smilax*, bearing a petiolate leaf, and two tendrils in place of stipules.——*Fig.* 274. A phyllode of a species of Acacia.

Tendrils of Leaves.—Any part of the leaf may also become transformed into a tendril. Thus,—1st. The midrib of the blade of a simple leaf may project beyond the apex, and form a tendril, as in *Gloriosa superba*; or some of the leaflets of a compound leaf may become transformed into branched tendrils (*fig.* 266), as in many species of Leguminosæ. 2nd. The petiole may become cirrhose (*fig.* 272, *v.*) And, 3rd. The stipules may assume the form of tendrils, as in many species of *Smilax* (*fig.* 273).

Phyllodes.—In the leaves of some Acacias (*fig.* 274), certain species of *Eucalyptus*, and of other plants, the parts forming the fibro-vascular tissue of the petiole, instead of remaining till they reach the blade before separating, begin to diverge as soon as they leave the stem or branch and become connected by parenchyma as in the ordinary blade of a leaf. To such petiole the name of *phyllode* has been applied. In some cases, as in *Acacia heterophylla*, the phyllode is terminated by a true compound blade, and its nature is thus clearly ascertained, but in most instances no such blade is produced. These phyllodes may be distinguished from true blades, not only by the occasional production of a compound lamina as just mentioned, but also by other circumstances. Thus,—1st. By their venation, which is more or less parallel (*fig.* 274) instead of reticulated, as is the case generally in Dicotyledons, in which class of plants they alone occur. 2nd. By their being placed nearly or quite in a vertical direction—that is, turning their margins upwards and downwards instead of their surfaces. And 3rd. By their two surfaces resembling each other, whereas in true blades a manifest difference is commonly observable between their upper and lower surfaces. (See also Leaves of Dicotyledonous Plants, page 175.)

Ascidia or Pitchers.—These are the most remarkable of all the anomalous forms presented by leaves. They may be seen in the species of *Nepenthes* or Pitcher Plants (*fig.* 275), in the species of *Sarracenia* (*fig.* 276), and in many other plants. These curious organs may be either formed from the petiole, or the blade of the leaf. Thus in the species of *Sarracenia* (*fig.* 276), the pitcher appears to be produced by the folding inwards of the two margins of a phyllode, which unite below, and form a hollow body or pitcher; but they are still separate above, and thus indicate its origin. In the *Nepenthes* (*fig.* 275), the petiole first expands into a phyllode, then assumes the appearance of a tendril, and ultimately forms a pitcher, *p*; this is closed above by

FIG. 275.

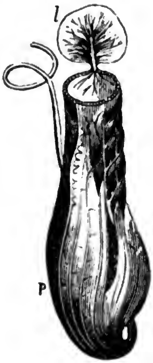


FIG. 276.

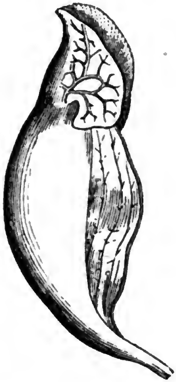


Fig. 275. Pitcher of a species of Pitcher Plant (*Nepenthes distillatoria*). *p*. Pitcher closed by the lid, *l*.——*Fig.* 276. Pitcher of *Sarracenia purpurea*.

a lid, *l*, called the operculum, which is united to it by an articulation, and is commonly regarded as a remarkable transformation of the blade. In another of these plants, the *Dischidia*, the pitchers are considered to be formed by the folding inwards and union of the margins of the blades of leaves.

8. GENERAL VIEW OF THE LEAVES IN THE THREE CLASSES OF PLANTS.

The leaves of plants in the three classes, as we have noticed in their description, present certain marked differences, which may be summed up as follows:—

1. Leaves of Dicotyledonous Plants.—In these the venation is commonly reticulated; but in a few plants, as *Ranunculus Lingua*, the so-called blades have parallel veins, and have been therefore considered by some botanists as presenting exceptions to the ordinary reticulated venation of Dicotyledons; but these are not usually regarded as true blades, but as varieties of phyllodes or transformed petioles, from which they only differ in being placed horizontally. (See page 173.)

The leaves of Dicotyledons are very commonly articulated to the stem or branch, often compound, and variously indented at their margins, or incised in different ways.

2. Leaves of Monocotyledonous Plants.—In these the venation is commonly more or less parallel; but the leaves generally of plants of the order Smilaceæ and of four other allied orders, as well as some in the Araceæ, present exceptions to this character, for in them the veins branch in various directions and form a network, as in the leaves of Dicotyledons. Some of these plants, as the Smilaceæ and the four allied orders, were therefore separated from other Monocotyledons by Lindley, and placed in a class by themselves, called Dictyogens, from the Greek word signifying a net. But this class has not been accepted by botanists.

In Monocotyledonous plants the leaves are also usually not articulated; and the margins of their blades are generally entire. They are also commonly simple; often sheathing at the base; and seldom have stipules, unless the ligule is to be considered as the analogue of those organs.

3. Leaves of Acotyledonous Plants.—In plants of this class when the leaves or fronds have veins, these are commonly arranged in a more or less forked manner.

Such leaves are usually not articulated; either sessile or stalked; frequently toothed or incised in various ways; and often highly compound.

CHAPTER IV.

ORGANS OF REPRODUCTION IN THE PHANEROGAMIA.

UNDER the head of Organs of Reproduction we include the Flower and its Appendages. They are called reproductive organs because they have for their especial office the reproduction of plants by the formation of seed.

The parts of a flower are only leaves in a modified condition, or rather the *analogues* of these organs, or, more properly, *homologous formations* adapted for special purposes; and hence a flower-bud is analogous to a leaf-bud, and the flower itself to a branch the internodes of which are but slightly developed, so that all its parts are situated in nearly the same plane. As flower-buds are thus analogous to leaf-buds, they are subject to similar laws of arrangement and development.

Section 1. INFLORESCENCE OR ANTHOTAXIS.

The term *inflorescence* or *anthotaxis* is applied generally to indicate the floral axis and its ramification, or the arrangement of the flowers upon that axis. Under this head we have to examine—1st, the Leaf, from the axil of which the flower-bud or flower-buds arise; 2nd, the Stalk, upon which the flower or flowers are situated; and 3rd, the Kinds of Inflorescence.

1. THE BRACT.

Flower-buds, like leaf-buds, are terminal or axillary. In the latter case the leaves from which they arise are called *bracts* or *hypsophyllary leaves.* In strict language the term bract should be only applied to the leaf from the axil of which a solitary flower or a floral axis arises; while all other leaves which are found upon that axis between the bract and the flower properly so called, should be termed *bractlets* or *bracteoles* (*fig.* 286, *b*, *b*).

Bracts vary much in appearance, some of them being large, of a green colour, and in other respects resembling the ordinary leaves of the plant upon which they are placed, as in the Pimpernel (*fig.* 277, *a*, *a*); in which case they are called *leafy bracts*. In most cases, however, bracts, although very commonly of a greenish colour, are smaller than the foliage leaves which have preceded them; and in many plants they

FIG. 277.

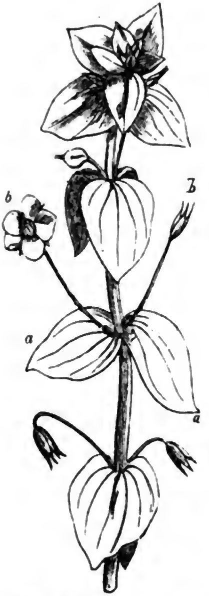


FIG. 278.

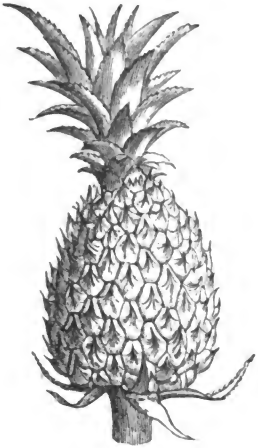


Fig. 277. Flowering stalk of the Pimpernel (*Anagallis arvensis*). *b*, *b*. Solitary flowers arising from the axil of leafy bracts, *a*, *a*. ——*Fig.* 278. Pineapple fruit (*Sorosis*), surmounted by a crown of empty bracts.

are also known from the true leaves not only by their position, but also by differences of colour, outline, texture, and other peculiarities. Thus the bracts forming the cupule of the Oak are hard and woody; in the Hop they are membranous; in certain plants of the Araceæ and Euphorbiaceæ coloured; in the flower-heads of the Compositæ scaly; and other modifications also occur.

It frequently happens that some of the bracts do not develop axillary flower-buds; this non-development of flower-buds appears to arise in some cases simply from accidental causes; but in others it occurs in a regular manner, as in the common Pineapple (*fig.* 278), where a number of bracts without flower-buds are placed at the apex of the inflorescence. Such bracts are called *empty*. When bracts are absent altogether, as in the plants of the natural order Cruciferæ, such plants are termed *ebracteated*; when bracts are present, the inflorescence is said to be *bracteated*.

Bracts follow the same law of arrangement as true leaves, being opposite, alternate, or whorled, in different plants. Bracts also vary in their duration, being *deciduous* or *persistent* in the same sense as leaves.

FIG. 279.

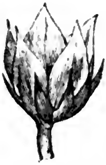


Fig. 279. Calyx of the Marsh-Mallow (*Althæa officinalis*) surrounded by an epicalyx or involucre.

Varieties of Bracts.—Bracts have received special names according to their arrangement and other characteristics. Thus the bracts of that kind of inflorescence called an Amentum or Catkin (see page 189) are usually of a scaly nature, and are therefore termed *squamæ* or *scales*; or the bracts are described as *squamous* or *scaly*. The bracts of the pistillate flowers of the Hop (*fig.* 300), are of like character.

When a circle or whorl of bracts is placed round one flower, as in the Marsh Mallow (*fig.* 279); or round a number of flowers, as in the Carrot (*fig.* 280) and numerous other Umbelliferous plants, they form what is termed an *involucre.* In some Umbelliferous plants, as for instance the Carrot, there are two involucres, one at the base of the primary divisions of the floral axis or general umbel (*fig.* 280, *a*); and another at the base of each of the partial umbels or umbellules, *b*, *b*; the former is then called the *general involucre*; and each of the latter an *involucel* or *partial involucre* (see page 195). In plants of the natural order Compositæ, such as the Marigold (*fig.* 281), and of some of the allied orders, a somewhat similar arrangement of bracts takes place, and the name of *involucre* is also applied in these cases. The constituent bracts of the involucre of Composite flowers have been termed *phyllaries.* Sometimes the bracts of an involucre grow together at their base,

FIG. 280.

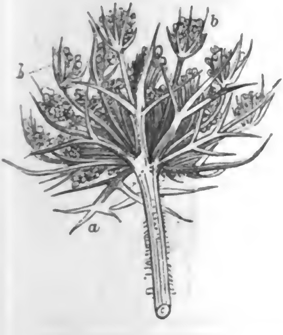


FIG. 281.

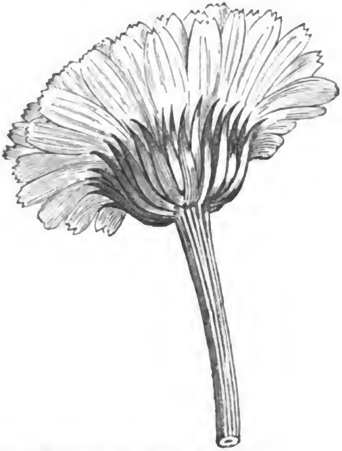


Fig. 280. Compound umbel of the Carrot (*Daucus Carota*). *a*. General involucre. *b*, *b*. Partial involucres or involucels.——*Fig.* 281. Capitulum of Marigold (*Calendula*), showing the flowers or florets enclosed in an involucre.

and form ultimately a sort of cup-shaped body surrounding the fruit, as the cup of the Acorn (*fig.* 282), and the husk of the Filbert or Hazel-nut (*fig.* 283); they then form what is called a *cupule.*

When a bract is of large size and sheathing, and surrounds one, or a number of flowers, so as to completely enclose them when in a young state, as in the Snowflake (*fig.* 284), the common Arum (*fig.* 285), and Palms (*fig.* 296), it is called a *spathe.* The spathe is generally found surrounding the kind of inflorescence called a *spadix* (page 189), as in the Arum and Palm; and it is also very common in other Monocotyledonous plants. The spathe may be either green like an ordinary leaf, or coloured. Sometimes the spadix of a Palm branches (*fig.* 296), and then we frequently find smaller spathes surrounding its divisions, which have been named *spathellæ.* Many botanists restrict the term spathe to the large enveloping bract of the spadix, and call the other bracts of a like character which enclose

FIG. 282.

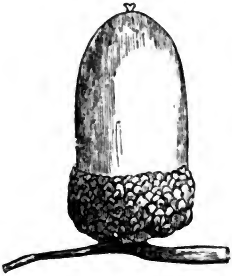


FIG. 283.

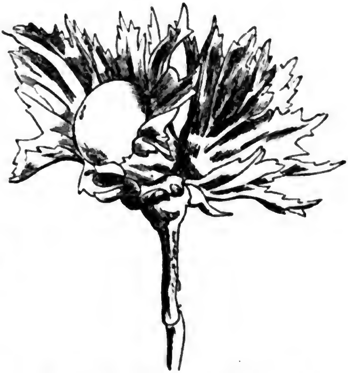


Fig. 282. Fruit of the Oak (*Quercus Robur*), surrounded by a cupule. ——*Fig.* 283. Fruit of the Hazel (*Corylus Avellana*), with cupule at the base.

only one or a few flowers, as frequently found in Monocotyledonous plants, *spathaceous bracts.*

Besides the bracts which surround the head of flowers in the Compositæ and form an involucre, it frequently happens that the individual flowers (*fig.* 286, *a*, *a*) are also provided with little bracts or bracteoles, *b*, *b*, which are then generally of a membranous nature, and colourless, as in the Chamomile. These are sometimes known as *paleæ*; but as this term is applied to certain special bracts found in Grasses (see below), they are better named *scales*, or by some other term which expresses their texture and character.

FIG. 284.

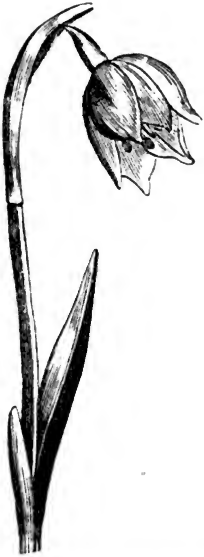


FIG. 285.

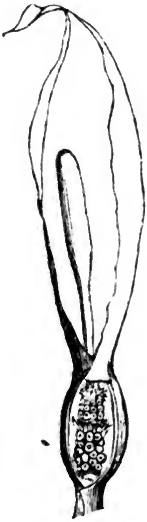


Fig. 284. Flower of the Spring Snowflake (*Leucojum vernum*).——*Fig.* 285. Spadix of Cuckoo-pint (*Arum maculatum*) enclosed in a spathe, a portion of which has been removed to show the flowers within it.

The only other bracts which have received special names are those found in plants of the Grass and Sedge orders. Thus, the partial inflorescence of a Grass, termed a *locusta* or *spikelet* (page 190), has at its base one or two bracts, which are called *glumes* (*fig.* 287, *gl*, *gl*); while in the Cyperaceæ *each* flower arises from the axil of one or two similar bracts. In the Grasses we also find that each flower has two other bracts, *ps*, *pi*, which are commonly called *pales* or *paleæ*; and also frequently at the base of the ovary there are two or more little scales, also of the nature of bracts, which are usually termed *squamulæ*, *glumellules*, or *lodiculæ* (*fig.* 422, *sp*).

FIG. 286.

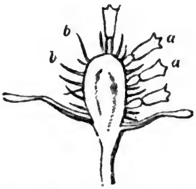


FIG. 287.

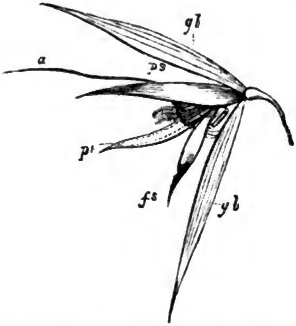


Fig. 286. Receptacle of the Chamomile (*Anthemis nobilis*) bearing flowers, *a*, *a*, and bracts or bracteoles, *b*, *b*: the latter are sometimes termed *Pales*. The receptacle is here drawn much too large at the apex, it should be conical.——*Fig.* 287. Locusta or spikelet of the Oat (*Avena sativa*). *gl*, *gl*. Glumes. *ps*, *pi*. *Paleæ* or *Pales*. *a*. Awn arising from the dorsum of the outer pale, *ps*. *fs*. An abortive flower.

2. THE PEDUNCLE OR FLOWER-STALK.

The term peduncle is applied to the stalk of a solitary flower, whether axillary (*fig.* 277, *b*, *b*), or terminal (*fig.* 307), or to a floral axis which bears a number of sessile flowers (*fig.* 19, *p*); or if the floral axis branches and each branch bears a flower (*fig.* 301), the main axis is still called a *peduncle*, and the stalk of each flower a *pedicel*; or if the axis be still further subdivided, the general name of peduncle (*fig.* 303) is applied to the whole, with the exception of the stalks immediately supporting the flowers, which are in all cases called pedicels. When the floral axis is thus branched, it is better to speak of the main axis as the *primary axis* (*fig.* 303, a), its divisions as the *secondary axes* a'', and their divisions as the *tertiary axes* a''', &c.

FIG. 288.

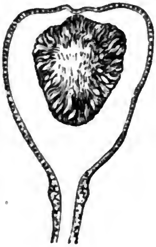


FIG. 289.

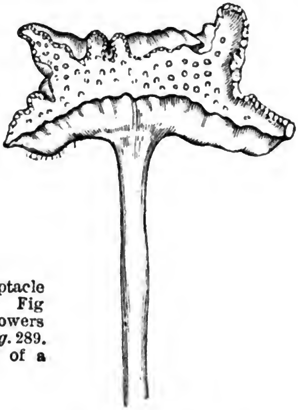


Fig. 288. Pear-shaped receptacle (*hypanthodium*) of the Fig (*Ficus Carica*), bearing flowers on its inner surface.——*Fig.* 289. Receptacle (*cœnanthium*) of a species of *Dorstenia*.

Under certain circumstances peduncles have received special names. Thus, when a peduncle is elongated, and gives off from its sides sessile flowers (*fig.* 19, *fl*), or branches bearing flowers (*fig.* 303), it is called the *rachis* or *axis*; but if, instead of being elongated in a longitudinal direction, it becomes shortened, more or less dilated, and commonly bearing numerous flowers, it is termed the *receptacle* (*fig.* 286). This receptacle varies very much in form; thus, it is flattened in the Cotton Thistle, conical in the Chamomile, concave and fleshy in the Dorstenia (*fig.* 289), pear-shaped and hollowed out in the Fig (*fig.* 288); or it assumes a variety of other intermediate forms.

When plants which have no aerial stem bear flowers, the peduncle necessarily arises at, or under the ground, in which case, whether bearing one or more flowers, it is called a *scape* or *radical peduncle* (*fig.* 284), as in the Tulip and Hyacinth.

In *form* the peduncle is generally more or less cylindrical, but besides the departure from this ordinary appearance as exhibited by the receptacle just described, it frequently assumes other forms. Thus, it may become more or less compressed, or grooved in various ways, or excessively enlarged during the ripening of the fruit, as in the Cashew-nut; or it may assume a spiral appearance, as in the *Vallisneria*; or become spiny, or transformed into a tendril; or it may be hollowed out at its apex, so as to form a cupshaped body, to which the lower part of the calyx is attached, as in *Eschscholtzia*; or other modifications may occur.

In some cases again, the peduncle or pedicel becomes flattened and assumes the form of a phyllode, when it is termed *foliaceous* or *phylloid*; or it is called a *phylloclade* or *cladode*. Examples of this occur in the Butcher's Broom (*fig.* 290), where the flowers arise from its surface, and in *Xylophylla*, in which they are attached to its margins. In other plants the peduncle, or several peduncles united, assume an irregular flattened appearance, somewhat resembling the fasciated branch already described (page 107), and bear numerous flowers in a sort of crest at their extremities, as in the Cockscomb; and in the Cauliflower, where the united fleshy branches of the peduncle form a rounded mass bearing on its upper part abortive flowers.

In some cases, the peduncle, instead of arising in the axil of a bract, may become *extra-axillary* by contracting adhesions to the axis or other parts. Thus, in the Lime-tree (*fig.* 291), the peduncle adheres to the midrib of the bract, *b*, for some distance, and then becomes free; while in many Solanaceæ, as in the Woody Nightshade (*fig.* 246), the peduncle also becomes extra-axillary by forming adhesions to the stem or a branch in various ways.

With respect to their duration the peduncle and pedicel vary. Thus, they are said to be *caducous*, when they fall off soon after the opening of the flower,

FIG. 290.

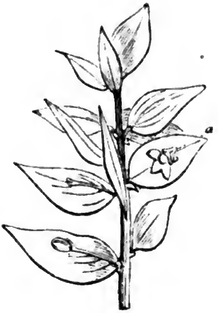


FIG. 291.

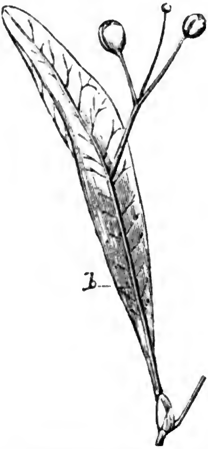


Fig. 290. Portion of a branch of the Butcher's Broom (*Ruscus aculeatus*), with phylloid pedicels bearing flowers, *a*.——*Fig.* 291. Peduncle of the Lime tree (*Tilia europæa*) attached to the bract, *b*.

as in the staminate or male flowers of a catkin; they are *deciduous*, when they fall off after the fruit has ripened, as in the Cherry; they are *persistent* if they remain after the ripening of the fruit and dispersion of the seed, as in the Dandelion; and they are said to be *excrescent*, if they enlarge or continue to grow during the ripening of the fruit, as in the Cashew-nut.

3. KINDS OF INFLORESCENCE.

The term inflorescence is used generally to indicate the arrangement of the flowers upon the floral axis or peduncle, and as these are variously placed we have a number of different kinds of inflorescence, to each of which a particular name is applied. All the regular kinds may be arranged in two divisions, which are usually called *Indefinite* or *Indeterminate*, and *Definite* or *Determinate Inflorescence.* The former is also termed *Botryoid* or *Botryose*; and the latter *Terminal* and *Cymose Inflorescence.* In the former, the primary floral axis is terminated by a growing point, analogous to the terminal leaf-bud of a stem or a branch : hence such an axis has the power of either growing in an upward direction in the same manner as the terminal leaf-bud of a stem or branch has the power of elongating, and thus adding to its length; or of dilating more or less horizontally. There is consequently no necessary limit to the growth of such an axis, and hence the name of Indeterminate or Indefinite which is applied to it. Such an axis as it continues to grow upwards develops on its sides other flower-buds, and these, like the buds of a stem or branch, are commonly situated in the axil of leaves which are here called bracts, as we have seen. All the flowers therefore of an Indefinite Inflorescence must be necessarily *lateral* or *axillary*, and hence this inflorescence is also termed *axillary.* The general characters of *Indefinite*, *Indeterminate*, or *Axillary Inflorescence*, depend therefore upon the indefinite growth of the primary axis; while the secondary, tertiary, and other axes which are developed from it are terminated by flower-buds. In the *Definite* or *Determinate Inflorescence*, on the contrary, the primary axis is terminated at an early period by the production of a flower-bud; such an axis has therefore a limit at once put to its growth in an upward direction, and hence the names of *Definite*, *Determinate*, or *Terminal*, applied to it. Each of these divisions also presents us with several modifications, which we now proceed to describe.

1. INDEFINITE, INDETERMINATE, OR AXILLARY INFLORESCENCE.—The simplest kind of inflorescence in this class is that presented by such plants as the Pimpernel (*fig.* 277), in which solitary flowers, *b*, *b*, are developed in the axils of what are commonly regarded as the ordinary leaves of the plant, *a*, *a*, although properly leafy bracts, the primary axis continuing to elongate in an upward direction and bearing other leaves and flowers. The flowers are then said to be *solitary* and *axillary*. When such flowers are arranged in whorls round the stem, as in the common Mare's Tail, each flower being axillary to a leafy bract (*fig.* 292), they are said to be *whorled*.

FIG. 292.

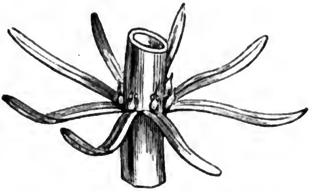


Fig. 292. Whorled leaves or bracts and flowers of Mare's Tail (*Hippuris vulgaris*).

When a number of flowers instead of a single one are developed upon an elongated, shortened, or dilated peduncle, placed at the extremity of a branch or in the axil of a bract, a number of kinds of inflorescence arise. All these depend upon the extent to which the floral axis branches, the mode in which the branching takes place, the comparative lengths of the flower-stalks, and other subordinate circumstances. It will be convenient to describe these various modifications under two heads—1st, those kinds of Indefinite Inflorescence with an Elongated Primary Axis; and 2nd, those with a Shortened or Dilated Primary Axis.

In all kinds of indefinite inflorescence it will be found that the flower-buds always open in succession from the base to the apex if the axis is elongated (*figs.* 19, *fl*, and 293), hence these inflorescences have been also called *acropetal* or *ascending*; or from the circumference towards the centre if the axis is depressed or dilated (*fig.* 304), therefore such forms are also called *centripetal.* This acropetal or centripetal order of expansion necessarily arises from the mode of development of such kinds of inflorescence; thus, the flower-buds situated at the base of an elongated axis are those that are first formed and are consequently the oldest; for as the axis elongates upwards, it is continually producing other flower-buds, the age of which necessarily decreases as we approach the growing point or apex; and hence as flower-buds open in the order of their age, it follows that those at the base will open first, and that the order of expansion will proceed gradually upwards towards the apex, or *acropetally.* In the same way the flower-buds situated at the circumference of a shortened or dilated axis are first formed, and those nearest the centre or growing point last, and therefore their expansion will proceed from the circumference to the centre, or centripetally.

FIG. 293.

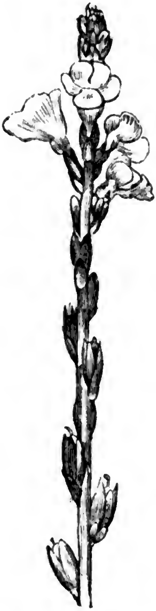


Fig. 293. Spike of Vervain (*Verbena*).

A. *Kinds of Indefinite Inflorescence with an Elongated Primary Axis.*—These are as follow:—

a. *The Spike.*—This is a kind of inflorescence in which the elongated peduncle bears sessile flowers, as in the Verbena (*fig.* 293), and Broom-rape (*fig.* 19, *fl*).

There are five other kinds of indefinite inflorescence, which are simply modifications of the spike, as follows:—Thus, the *Amentum* or *Catkin* is a kind of spike which usually bears barren flowers—that is, only staminate (*fig.* 294), or only pistillate (*fig.* 295) ones. All plants with this kind of inflorescence are called *amentaceous* or *amentiferous*. Our trees afford numerous examples, as the Oak, Willow, Birch, and Poplar.—*The Spadix* is a spike with a succulent axis, in which the individual flowers have no special bracts, but the whole inflorescence enclosed in that variety of bract which is called a spathe. This is well seen in the Cuckoo-pint (*fig.* 285). Sometimes the spadix branches, as in Palms (*fig.* 296), in which case it is called *compound* or *branching*. The term spadix is also frequently applied to a succulent spike, whether enveloped in a spathe or not, as in the Sweet Flag.—*Locusta* or *Spikelet* is the name applied to the partial inflorescence of Grasses (*fig.* 287), and of plants of the Sedge order. In Grasses it is a spike with a few flowers, and these destitute of a true

FIG. 294.

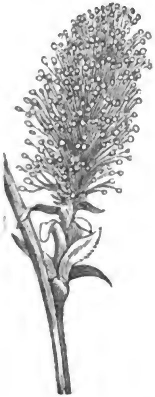


FIG. 295.

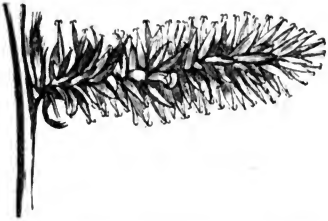


Fig. 294. **Staminate amentum or catkin of a species of Willow (*Salix*).——*Fig.* 295. Pistillate or carpellary amentum of a species of Willow.**

calyx and corolla, their place being occupied by *paleæ* or *pales* (*fig.* 287, *ps*, *pi*), and the whole inflorescence surrounded at the base by one or two empty bracts (*glumes*), *gl*, *gl*. These spikelets may be either arranged sessile on the elongated floral axis (*fig.* 297), as in Wheat, or they may be placed on a more or less branched axis, as in the Oat (*fig.* 298). The spikelets of plants of the Sedge order present certain peculiarities, but they are essentially of the same nature as those of Grasses.—*The Cone* is a kind of spike, found

FIG. 296.

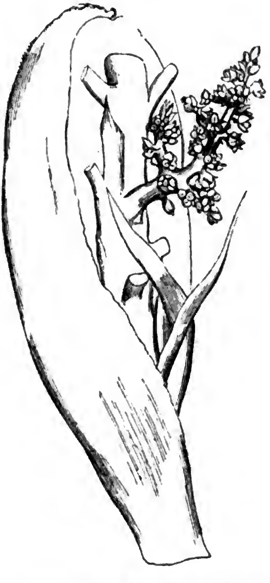


FIG. 297.

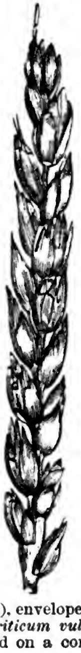


Fig. 296. Branched spadix of a Palm (*Chamærops*), enveloped in a spathe.——*Fig.* 297. Inflorescence of Wheat (*Triticum vulgare*), consisting of numerous sessile spikelets arranged on a common axis (*rachis*).

in plants of the order Coniferæ, as the Larch, Pine, and Fir (*fig.* 299). It is composed of a collection of imbricated scales or open carpels arising from the axils of bracts, and bearing one or two ovules at their base (*fig.* 13, *ov*).—*The Strobilus* or *Strobile* is a kind of spike formed of persistent membranous bracts or scales, each of which bears at its base a pistillate flower. It is seen in the Hop (*fig.* 300). It is but a slight modification of the ordinary amentum.

FIG. 298.

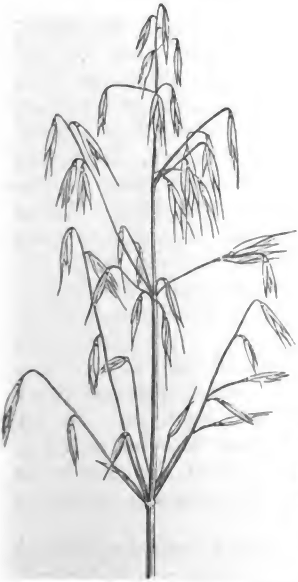


FIG. 299.

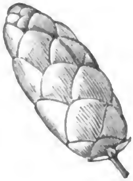


FIG. 300.

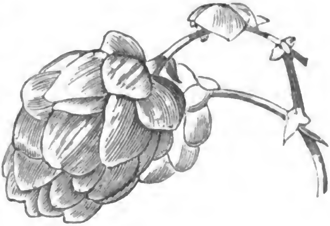


Fig. 298. Branched or panicled inflorescence of the Oat (*Avena sativa*).——*Fig.* 299. Cone of Hemlock Spruce (*Pinus* or *Abies canadensis*).——*Fig.* 300. Strobile of the Hop (*Humulus Lupulus*).

b. *The Raceme.*—This name is applied to that form of inflorescence in which the elongated peduncle bears flowers placed on pedicels of nearly equal length (*fig.* 301). Examples occur in the Mignonette and Laburnum.

FIG. 301.

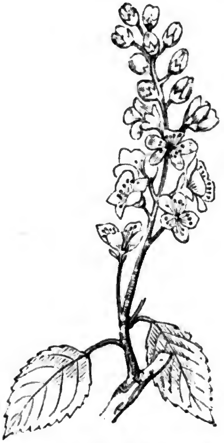


Fig. 301. Raceme of a species of Cherry (*Prunus*).

c. *The Corymb.*—This is a kind of raceme in which the pedicels are of different lengths (*fig.* 302), viz. those, a'' a'', at the base of the primary axis, a', longer than those towards and at the apex, so that the whole form a level, or nearly level top. Examples may be seen in some species of *Prunus* (*fig.* 302). When the stalks or secondary axes of a corymb (*fig.* 303, a''), instead of bearing flowers immediately, divide and form tertiary, a''' a''', or other axes, upon which the flowers are then placed, it is termed *compound* or *branching*, as in some species of *Pyrus*. This may also be called a *panicled corymb*, to distinguish it from the former or *simple corymb*, which may also be termed a *racemose corymb*.

In several species of *Juncus* and *Luzula*, the pedicels of the lower flowers are so long that they are elevated above the upper ones, in which case the inflorescence is sometimes distinguished by the term *anthela*.

d. *The Panicle.*—This is a form of inflorescence in which the secondary axes, instead of bearing flowers directly, branch, and form tertiary axes, &c., the ultimate subdivisions of which bear the flowers. Examples occur in the *Yucca gloriosa*, and in the general arrangement of the partial inflorescences of the Oat (*fig.* 298).

When a panicle is very compact, it is sometimes termed a *thyrsus* or *thyrse*, as in the Lilac.

B. *Kinds of Indefinite Inflorescence with a Shortened or Dilated Primary Axis.*—Of these we distinguish two principal varieties:—the Capitulum or Anthodium, and the Umbel.

a. *The Capitulum, Anthodium, or Head.*—This inflorescence was formerly called a *Compound Flower*; and its involucre a *Common Calyx*. It is usually formed by a number of sessile flowers, or florets as they are called from their small size, crowded together on a receptacle, and the whole surrounded by an involucre (*fig.* 281); but in some cases the florets are but very few in number, and in some capitula the involucre is absent. The receptacle, as we have seen (page 184),

FIG. 302.

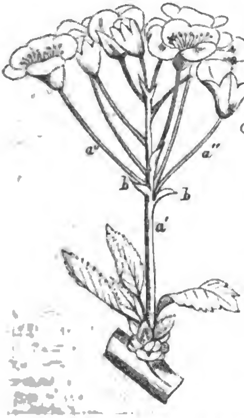


FIG. 303.

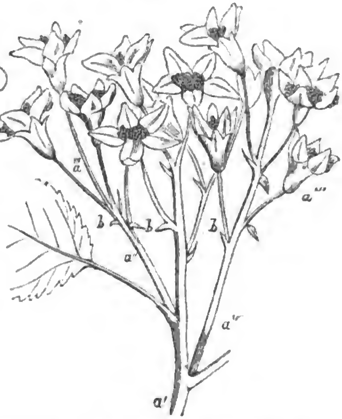


Fig. 302. Simple or racemose corymb of a species of *Prunus*. a'. Primary axis, bearing bracts, b, b, from the axils of which secondary axes or pedicels, a'', a'', arise.——*Fig.* 303. Compound, branching, or panicled corymb of the Wild Service tree (*Pyrus torminalis*). a'. Primary axis. a'', a''. Secondary axes. a''', a'''. Tertiary axes. b, b, b. Bracts.

is of various forms, which influence in a corresponding degree the appearance of the capitula. This kind of indefinite inflorescence, as well as all others with a shortened or dilated primary axis, exhibit a centripetal order of expansion. This may be well seen in the capitulum of the Scabious (*fig.* 304), where the outer florets are fully expanded, those within them less so, and those in the centre in an unexpanded condition. The capitulum is the universal form of inflorescence in plants of the natural orders Compositæ and Dipsacaceæ; and it is also found, more or less, in some orders allied to these.

FIG. 304.

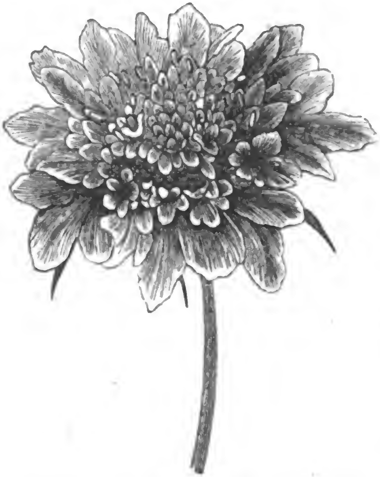


FIG. 305.

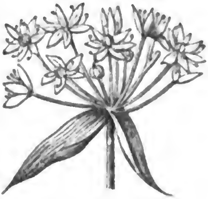


Fig. 304. Capitulum of Scabious (*Scabiosa*). The outermost florets may be observed to be more expanded than the inner. ——*Fig.* 305. Simple umbel of a species of *Allium*.

b. *The Umbel.*—When the primary axis is shortened, and gives off from its apex a number of pedicels of nearly equal length, each bearing a flower, and the whole arranged like the ribs of an umbrella, an *umbel* is formed (*fig.* 305), as in the Cowslip. When the secondary axes or pedicels themselves divide, and form tertiary axes, which are also arranged in an umbellate manner, a *compound umbel* is produced. This is seen in the Carrot (*fig.* 280), the Fennel (*fig.* 306), and other allied plants, which are hence called *umbelliferous*, and give the name to the natural order Umbelliferæ. In the compound umbel (*fig.* 306), the primary umbel, *a*, is called the *general umbel*, and the other umbels, *b*, *b*, *b*, formed by the divisions of this, *partial umbels* or *umbellules*.

FIG. 306.

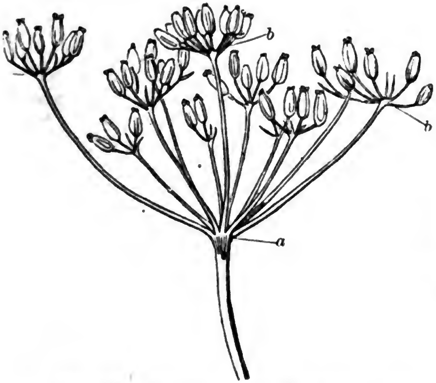


FIG. 307.

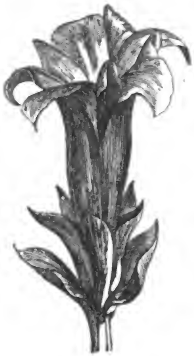


Fig. 306. Compound umbel of Fennel. *a*. General umbel. *b*, *b*, *b*. Partial umbels or umbellules.——*Fig.* 307. Portion of the floral axis of a species of Gentian (*Gentiana acaulis*), terminated by a solitary flower, below which are two bracts.

2. DEFINITE, DETERMINATE, OR TERMINAL INFLORESCENCE.—In all kinds of definite inflorescence the primary axis, as we have seen, page 186, is arrested in its growth at an early age by the development of a terminal flower-bud, and if the axis bears no other flowers this is called a *solitary terminal* flower, and is the simplest form of this variety of inflorescence. Examples of this may be seen in the Stemless Gentian (*fig.* 307). When other flowers are produced on such

an axis, they must necessarily arise from axillary buds placed below the terminal flower-bud; and if these form secondary axes (*fig.* 308, a''), each axis will in like manner be arrested in its growth by a terminal flower-bud f''; and if other axes, a''', are developed from the secondary ones, these also must be axillary, and will be arrested in a similar manner by flowers f''', and these axes may also form other axes of a like character, and so on. Hence this mode of inflorescence is *definite*, *determinate*, or *terminal*, in contradistinction to the former or indefinite mode of inflorescence, where the primary axis elongates indefinitely unless stopped by some extraneous cause. In definite inflorescences the flower-buds necessarily follow a different order of expansion from those of indefinite inflorescences, because in them the terminal flower is the first developed and consequently the oldest (*fig.* 308, f'), and other flower-buds are produced in succession from the apex to the base, if the axis be elongated, f'', f'''; or if shortened or dilated, from the centre to the circumference. The

FIG. 308.

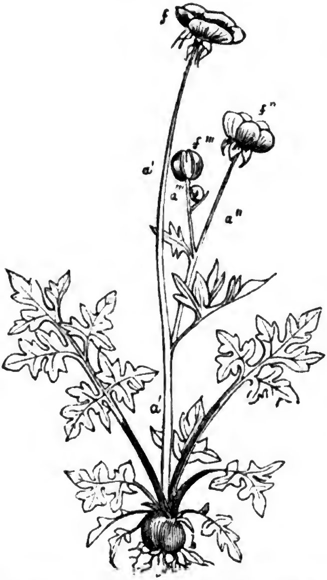


Fig. 308. A plant of *Ranunculus bulbosus.* a', a'. Primary axis terminated by a fully expanded flower, f'. a''. Secondary axis, which is also terminated by a flower, f'', not so fully developed as f'. a'''. Tertiary axis terminated by a flower-bud, f''', which is less developed than f' and f''.

uppermost flower-bud of the elongated axis (*fig.* 310, *f'*), and the central one of the shortened or dilated axis will accordingly open first (*fig.* 314); and the lowermost of the former (*fig.* 310 *f''*), and the most external of the latter, last. Such an order of expansion is therefore called *centrifugal* or *regressive.*

Kinds of Definite or Determinate Inflorescence.—The more important kinds of definite inflorescence are distinguished by special names as follows:—

a. *The Cyme.*—This term is applied generally to a definite inflorescence which is more or less branched, the whole being developed in a corymbose or somewhat umbellate manner, so as to assume either a flattened head, as in the Elder; or a rounded one, as in the Hydrangea; or more or less spreading, as in the Chickweed (*fig.* 309). In the more perfect and compact form of cyme, as found in the Elder, the flower-buds are all nearly perfect before any of them open, and then the flowering takes place rapidly, commencing in the centre of the cyme, and then in the centre of each of its divisions, and thence proceeding in an outward direction; and as the central flower of each cluster corresponds to the apex of a branch, the expansion of the whole is centrifugal. In the Chickweed (*fig.* 309), and many other plants, the formation of the secondary, tertiary, and other axes, a'', a''', a'''', goes on throughout the growing season, and in such cymes, which are usually of a more or less spreading nature, the centrifugal order of expansion may be well observed.

The above cymes are sometimes characterised according to the number of their branches; thus they are dichotomous, as in the Chickweed (*fig.* 309), when the primary axis a' is terminated by a flower, at the base of which are two bracts, each of which develops in its axil secondary axes, a'', a'', ending in single flowers; and at the base of each of these flowers there are also two other bracts, from which tertiary axes,

a''', a''', are developed, also terminated by flowers, and so on; and as the division in this case always takes place into two branches, the cyme is said to be *dichotomous*. The dichotomous cyme is also called a *biparous cyme* or *dichasium*. This is not a true dichotomous branching (*see* page 105), but only

FIG. 309.

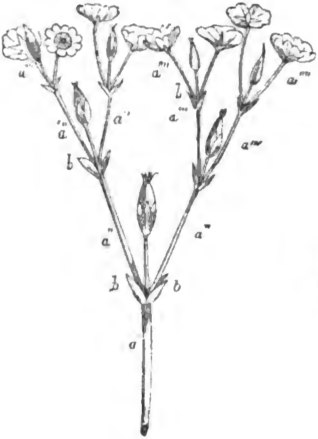


FIG. 310.

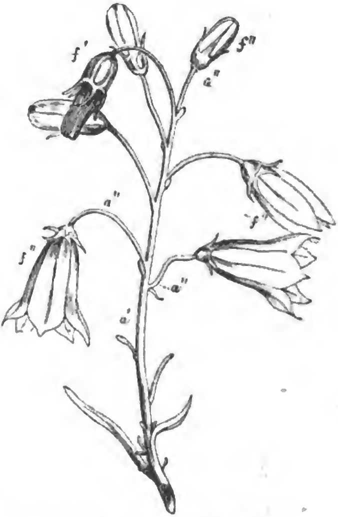


Fig. 309. Dichasial cyme or Dichasium of a species of Chickweed (*Cerastium*). a'. Primary axis terminated by a flower. a'', a''. Secondary axes, two in number, arising from the axils of opposite bracts, b, b, and terminated also by flowers. a''', a''', a''', a'''. Tertiary axes, four in number, arising from bracts, b, and bearing other bracts, b, from which the quaternary axes, eight in number, arise, a'''', a'''', a''''. The flowers are more developed on the primary axis than on the other axes; thus the one terminating that axis is in the state of fruit; the flowers of the axes of a'' and a''' are also in fruit, but less developed than that of a', while in the axes a'''' the flowers only are expanded.——*Fig.* 310. Racemose cyme of a species of *Campanula*. a'. Primary axis, terminated by a flower, f', which is already withering. a'', a'', a''. Secondary axes, each ending in a flower, f'', f'', f''.

apparently so, in consequence of the greater development of the lateral axes as compared with that of the primary axis.

Other cymes are also frequently characterised as corymbose, or umbellate, from their resemblance, except in the order of the expansion of their flowers, to the true corymb, or umbel. Again, when a cyme has sessile flowers, or nearly so, it may be described as a *spiked cyme*; when it has its flowers on pedicels of nearly equal length, as in the *Campanula* (*fig*. 310), a *racemose cyme*; or when it assumes the form of a panicle, as in the Privet, a *panicled cyme.*

Other kinds of definite inflorescences have also received particular names, as the *Helicoid* or *Scorpioid Cyme*, the *Fascicle*, the *Glomerule*, and the *Verticillaster.*

b. *Helicoid or Scorpioid Cyme.* —This is a kind of cyme in which the flowers are only developed on one side, and in which the upper extremity is more or less coiled up in a circinate manner, so as frequently to resemble the shell of a snail, or the tail of a scorpion; hence the names *helicoid* and *scorpioid* by which such a cyme is distinguished. This kind of cyme is especially developed in plants of the Boraginaceæ, as the Forget-me-not (*fig*. 311). In these plants the bracts are alternate; but such a cyme may also occur in plants with opposite bracts, and the manner in which it is most commonly believed to be formed in the two cases is as follows:—Thus in plants where the bracts are opposite, it arises by the regular non-

FIG. 311.

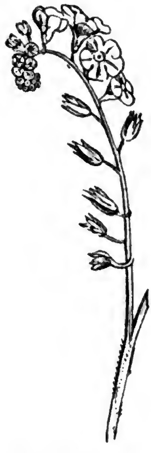


Fig. 311. Scorpioid cyme of the Forget-me-not (*Myosotis palustris*).

development of the axes on one side, while those on the other side are as regularly produced. This will be readily explained by a reference to the diagram (*fig.* 312). Here *a* represents the flower which terminates the primary axis; at the base of this flower are two bracts, only one of which develops a secondary axis, *b*, which is in like manner terminated by a flower, at the base of which are also two bracts, only one of which (i.e. that on the same side with the first) produces a tertiary axis, *c*, also terminated by a flower with two bracts at its base, one of which gives origin to another axis, *d*, placed in a similar manner; and so on. In consequence of this one-sided (or, as it is called, *secund*) manner in which the successive axes are produced, the direction of the inflorescence is constantly drawn to one side at the formation of each axis, and that in proportion to the size of the angle formed by it with the axis from which it springs,

FIG. 312.

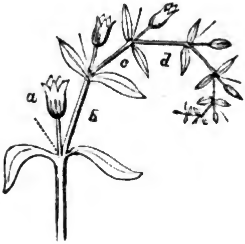


FIG. 313.

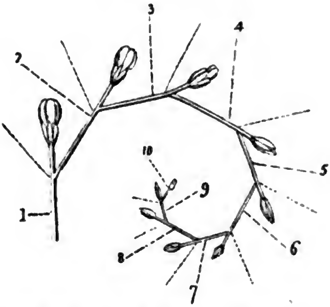


Fig. 312. Diagram to illustrate the formation of a helicoid cyme in a plant with opposite bracts. *a.* Flower terminating the primary axis. *b.* Secondary axis. *c.* Tertiary axis. *d.* Quaternary axis. Each axis is terminated by a flower. The dotted lines represent the position of the undeveloped axes.——*Fig.* 313. Diagram to illustrate the formation of a helicoid cyme in a plant with alternate bracts. The figures represent the respective axes, and the dotted lines below the flowers the position of the bracts.

and thus when the angle is large, and many flowers are produced in succession, the upper extremity becomes completely coiled up in a circinate manner. In plants with alternate bracts, the helicoid cyme arises from the primary axis (*fig.* 313, 1) being terminated by a flower, and giving off below it from the uppermost bract a secondary axis 2, which also terminates in a flower, and gives off below it in like manner from the same side as the former a third axis 3, which likewise terminates in a flower, and so on as seen by the figures.

The terms helicoid and scorpioid are thus used by us indifferently to indicate the same form of *unilateral, monochasial*, or *uniparous cyme*. This is the sense in which they are used by De Candolle, Le Maout, Decaisne, Hooker, and many other botanists. We are induced to do so, because their nature is at present by no means well defined, and from the synonymy being best understood and practically exemplified in Descriptive Botany, at least in this country. But most Continental botanists now distinguish two kinds of uniparous cymes, under the respective names of *helicoid cyme* or *bostryx*, and *scorpioid cyme* or *cicinnus*. Thus in what is termed the *helicoid cyme*, the successive lateral branches always arise from the same side,—that is, either right or left of the main axis (*see* page 104 and *fig.* 145, A), as in *Hemerocallis*; while in the *scorpioid cyme*, the successive lateral axes are developed alternately right and left of the main axis (*fig.* 145, B), as in the Rock Rose and Sundew.

c. *The Fascicle or Contracted Cyme.*—This name is applied to a cyme which is rather crowded with flowers placed on short pedicels of nearly equal length, and arising from about the same point, so that the whole forms a flattened top, as in the Sweet William and some other plants of the Pink order to which it belongs.

d. *The Glomerule.*—This is a cyme which consists of a few sessile flowers, or of those where the pedicels are very short, collected into a rounded head or short spike. Examples may be seen in Labiate plants. (See *Verticillaster.*)

e. *The Verticillaster.*—This kind of cyme is seen in the White Dead-nettle (*fig.* 314), and usually in other plants of the Labiate order to which it belongs. In it the flowers appear at first sight to be arranged in whorls around the axis, but upon examination it will be seen that, in each apparent whorl, there are two clusters or glomerules axillary to two leafy bracts, the central flowers of which open first, and hence the mode of expansion is centrifugal. To these false whorls thus formed of two axillary glomerules, the term *verticillaster* is frequently applied; but this variety of inflo-

FIG. 314.

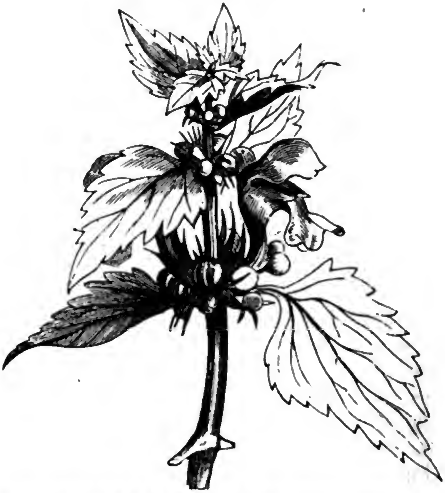


Fig. 314. **Flowering stalk of the White Dead-nettle (*Lamium album*).**

rescence is sometimes regarded as a contracted form of the dichasium.

Besides the above regular kinds of inflorescence, all of which are comprehended under the two divisions of indefinite and definite, there is a third division, which consists in a combination of these two forms, to which the term *mixed inflorescence* has been accordingly given.

3. MIXED INFLORESCENCE.—This kind of inflorescence is by no means uncommon. It is formed by the general inflorescence developing in one way, and the partial or individual inflorescence in another. Thus in plants of the natural order Compositæ (*fig*. 315), the terminal capitulum is the first to expand, and the capitula, as a whole, are therefore developed in a centrifugal manner; while the individual capitula open their flowers from the circumference to the centre, or centripetally; hence, here the general inflorescence is *definite*, and each partial inflorescence *indefinite*. In Labiate plants we have a directly reverse arrangement, for here the individual verticillasters open their flowers centrifugally (*fig*. 314), but the general inflorescence is centripetal; hence the general inflorescence is here *indefinite*, while each partial inflorescence is *definite*.

FIG. 315.

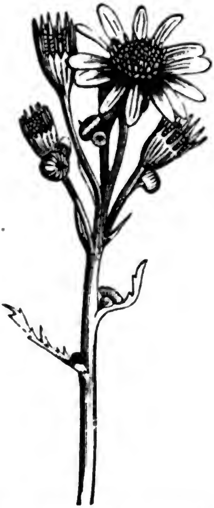


Fig. 315. Mixed inflorescence of a species of *Senecio*.

Section 2. OF THE PARTS OF THE FLOWER; AND THEIR ARRANGEMENT IN THE FLOWER-BUD.

1. PARTS OF THE FLOWER.

The Parts of a Flower have already been treated of in a general manner (page 18), and now, before describing them in detail, we must treat of their arrangement in the flower-bud.

2. ÆSTIVATION OR PRÆFLORATION.

As the general arrangement of the rudimentary leaves of the leaf-bud is called *vernation* (the spring state), or præfoliation, so the mode in which the different parts of the flower are disposed in the flower-bud is termed their *æstivation* (the summer state), or *præfloration*. The terms used in æstivation especially refer to the relative positions of the sepals and petals, because the stamens and carpels, from their peculiar forms, can give us no such arrangements of their parts as are exhibited by the more or less flattened parts of the floral envelopes.

In describing the modifications of æstivation, we have, as in the case of vernation, to include: 1st, the disposition of each of the component parts of the floral envelopes, considered independently of the others; and 2nd, the relation of the several members of either of the floral envelopes taken as a whole in respect to one another. With regard to the disposition of each of the component parts of the floral envelopes considered independently of the others, the same terms are used as in similar modifications of vernation (page 140), with the addition of the *crumpled* or *corrugated* form, which is not found in the parts of the leaf-bud. This latter variety may be seen in the petals of the Poppy and Rock-rose; and it derives its name from the parts being irregularly contracted into wrinkled folds.

With respect to the relation of the several members of either of the floral envelopes taken as a whole to one another, various modifications occur, all of which may be arranged in two divisions; namely, the *Circular*, and the *Imbricated* or *Spiral Æstivation.* The former includes all those varieties in which the component parts of the whorl are placed in a circle, and in nearly the same plane; and the latter those where they are placed at slightly different levels in a more or less spiral manner, and overlap each other.

1. *Varieties of Circular Æstivation.*—We distinguish three well-marked varieties of this, i.e. the *valvate*, *induplicate*, and *reduplicate.* The *valvate* (*fig.* 316) may be seen in the calyx of the Lime; in this variety the parts are flat or nearly so, and in contact by their margins throughout their whole length without any overlapping. When the component sepals or petals, instead of being simply flattened, are folded inwards at the points where they come in contact (*fig.* 317), the æstivation is *induplicate*, as in the calyx of some species of *Clematis.* When the margins are turned outwards under the same circumstances (*fig.* 318), the æstivation is *reduplicate*, as in the calyx of the Hollyhock, and in the corolla of the Potato.

FIG. 316.

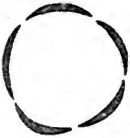


FIG. 317.

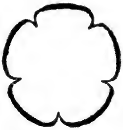


FIG. 318.

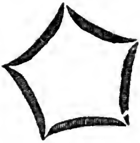


FIG. 319.

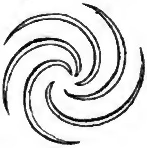


Fig. 316. Diagram to illustrate valvate æstivation.——*Fig.* 317. Diagram to illustrate induplicate æstivation.——*Fig.* 318. Diagram to illustrate reduplicate æstivation.——*Fig.* 319. Diagram to illustrate contorted or twisted æstivation.

When the parts of a whorl are placed as in the ordinary forms of circular æstivation, and one margin of each is directed obliquely inwards, and is overlapped by the part adjacent on that side, while the other margin covers the corresponding margin of the adjoining part on the other side, so that the whole presents a more or less twisted appearance (*fig.* 319), the æstivation is *contorted* or *twisted*. This kind of æstivation occurs frequently in the corolla, but is very rare in the calyx. Examples may be seen in the corolla of the Hollyhock and other Malvaceous plants. When in this variety of æstivation the component organs become united, they are frequently plaited, as in the corolla of the common Bindweed, in which case the æstivation is termed *plicate* or *plaited*.

2. *Varieties of Imbricated or Spiral Æstivation.*—We distinguish five varieties of this kind of æstivation, i.e. the *imbricate*, *convolute* or *enveloping*, *quincuncial*, *cochlear*, and *vexillary*. The true *imbricate* æstivation, as seen for instance in the calyx of *Camellia japonica* (*fig.* 320), is formed by the parts being placed at different levels, and overlapping each other more or less by their margins like the tiles on the roof of a house, the whole forming a spiral arrangement; this is a very common variety. When the parts, instead of merely overlapping, completely envelop each other, as in the corolla of *Camellia japonica*, the æstivation is frequently termed *convolute*; but this term is now more frequently applied to the contorted variety of æstivation, when the parts overlap to a considerable degree, as in the Wallflower. When the parts of a floral whorl are five in number, and these arranged in such a manner that there are two parts placed on the outside, two inside, and the fifth overlapping one of the internal by one margin, while it is itself overlapped on its other margin by one of the external parts, as in the corolla of the Rose, the æstivation is said to be *quincuncial* (*fig.* 321). In this kind of æstivation the spiral arrangement of the parts is well seen, and is indicated in the diagram by a dotted line. When in a quincuncial arrangement the second part of the cycle

becomes wholly internal instead of being external, the regularity of the quincunx is interrupted, and a variety of æstivation occurs, to which the name *cochlear* has been given (*fig.* 322). Familiar examples of this are afforded by the Snapdragon (*Antirrhinum majus*), and other allied plants. Another modification of imbricated æstivation occurs in the corolla of the Pea and other allied plants, where the superior petal 4, which is generally the largest, and called the *vexillum*, is folded over the others which are arranged face to face

FIG. 320.

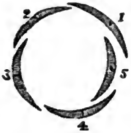


FIG. 321.

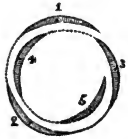


FIG. 322.

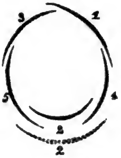


FIG. 323.

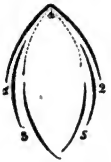


Fig. 320. Diagram to illustrate imbricate æstivation. The figures 1, 2, 3, 4, 5, show that the successive parts are arranged in a spiral manner.——*Fig.* 321. Diagram to illustrate quincuncial æstivation. 1 and 2 are external, 4 and 5 internal, and 3 is partly external and partly internal. The spiral arrangement is indicated by the dotted line.——*Fig.* 322. Diagram to illustrate cochlear æstivation. The part marked 2 in the preceding diagram is here wholly internal instead of external as in the quincuncial arrangement. The dotted line marked 2 indicates its normal position in the true quincuncial variety of æstivation.——*Fig.* 323. Diagram to illustrate vexillary æstivation. 1 and 2 form the alæ or wings, 3 and 5 the carina or keel, 4 the vexillum. (See *Papilionaceous Corolla.*)

(*fig.* 323). This kind of æstivation is commonly termed *vexillary*.

Besides the definite and constant relations which the parts of the floral envelopes have to one another in the flower-bud, they also have a definite and constant relation in the same plant to the axis upon which they are placed. In describing these positions we use the terms *anterior* or *inferior*, *superior* or *posterior*, and *lateral*. Thus, we call that organ *posterior* or *superior*, which is turned towards the axis; and that next the bract from the axil of which it arises, *inferior* or *anterior*. When there are four organs in a whorl, one will be *superior*, one *inferior*, and two *lateral*, as in the petals of the Wallflower (*fig*. 21, *p*). If there are five we have two arrangements. Thus, in the calyx of the flowers in the order *Leguminosæ*, two sepals are *superior*, two *lateral*, and one *inferior*; while in the corolla one petal is *superior*, two *inferior*, and two *lateral* (*figs*. 323 and 344). In plants of the Rose order (*Rosaceæ*), we have a precisely reverse position exhibited by the parts of the two floral envelopes; thus, here we have two sepals *inferior*, two *lateral*, and one *superior*; while in the corolla there are two petals *superior*, two *lateral*, and one *inferior* (*fig*. 343).

The term *anthesis* is sometimes used to indicate the period at which the flower-bud opens.

Section 3. THE FLORAL ENVELOPES.

1. THE CALYX.

We have already stated that the calyx is the outermost envelope of the flower, and that it is composed of one or more leafy organs called *sepals*. These sepals are usually green like true leaves, by which character, as well as by their position and less delicate texture, they may in most cases be distinguished from the petals. But in some plants the green colour disappears, and the calyx becomes coloured with the same tints as the corolla, or with some other bright hues. In such cases it is said to be *petaloid*, and the chief distinctive character between it and the corolla is then afforded by its position on the outside of the latter organ. The Fuchsia and Monkshood may be mentioned as affording familiar examples of such a calyx. In the Monocotyledonous plants generally, as in the Lily and Squill, the two floral envelopes are usually coloured, although rarely green, and in other respects so closely resemble each other, that we then use the collective name of *perianth* to indicate the two whorls taken together. When there is but one whorl of floral envelopes, as in the Goosefoot (*fig.* 24), it is customary with some botanists to call this the calyx, whether it is coloured or green; it is so termed in this volume. Other botanists, however, under such circumstances, call the whorl that is present a perianth; and others also apply it in all cases to flowers, whether of Monocotyledons or Dicotyledons, when the floral envelopes are all coloured as in the Lily, or all green as in the Dock. The term is also sometimes employed in a *general* sense to signify all the floral envelopes.

In their structure, venation, and characters generally, the sepals resemble the true leaves, and are covered like them with epidermis; this is also frequently furnished on the lower or outer surface with stomata, and also occasionally with hairs, glands, or other appendages. From the duration of the sepals being usually more transitory than that of foliage leaves, their veins as a rule essentially consist of spiral vessels, and are arranged like those of the leaves in the two classes of plants respectively—that is, reticulated in Dicotyledons, and parallel in Monocotyledons.

The sepals also exhibit various characters as regards their outline, form, apex, &c., although they are by no means so liable to variations in these particulars as the blades of true leaves. The terms used in defining these various modifications are applied in the same sense as with the blades of leaves.

Sepals are almost without exception destitute of a stalk, or, in other words, they are sessile upon the thalamus. They are also generally entire at their margins, although exceptions to this latter character occasionally occur: thus, in the Rose (*fig.* 324, *cf*), the sepals are incised; in many species of Dock toothed, and in other plants more or less lobed or partite.

In their direction, the sepals are either *erect* or turned upwards; *connivent* or turned inwards; *divergent* or spreading outwards; or *reflexed*, when their extremities are turned downwards.

The sepals may be either distinct from each other as in the Poppy, or more or less united into one body (*figs.* 326–328) as in the Pimpernel, Centaury, and Campion. In the former case, the calyx is usually termed *polysepalous* or *dialysepalous*; in the latter it is commonly called *monosepalous*. But this latter term is incorrect, as it indicates literally one sepal; and hence many botanists use instead the more correct term of *gamosepalous* calyx, as this simply implies that the sepals are united.

FIG. 324.

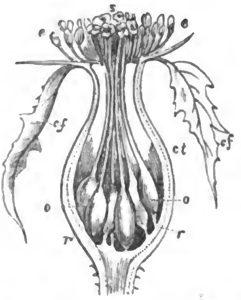


FIG. 325.

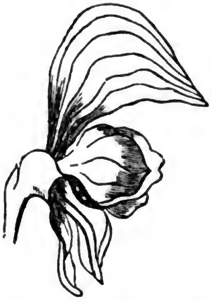


Fig. 324. Vertical section of the flower of the Rose. *r*, *r*. Concave thalamus, upon which are placed several carpels, *o*, *o*, each of which is furnished with a style and stigma, *s*. *e*, *e*. Stamens. *ct*. Tube of the calyx. *cf*, *cf*. Free portions of the calyx divided at their margins.——*Fig*. 325. Flower of Monkshood (*Aconitum Napellus*), with an irregular polysepalous calyx. The upper sepal is petaloid, and hooded or helmet-shaped.

1. POLYSEPALOUS OR DIALYSEPALOUS CALYX.—A polysepalous calyx may consist of two or more sepals, and is characterised accordingly. It is called *regular* if it consist of sepals of equal size and like figure or form, and arranged in a symmetrical manner, as in the Strawberry; and it is said to be *irregular* when these conditions are not complied with, as in the Monkshood (*fig*. 325).

2. Monosepalous or Gamosepalous Calyx.—When the sepals are united so as to form a monosepalous calyx, various terms are used to indicate the different degrees of union. Thus, the union may only take place near the base, as in the Pimpernel (*fig.* 326), when the calyx is said to be *partite*; or it may take place to about the middle, as in the Centaury (*fig.* 327), when it is *cleft* or *fissured*; or the sepals may be united almost to the top, as in the Campion (*fig.* 328), when it is *toothed*; or if the union is quite complete, it is *entire*. The number of partitions, fissures, or teeth is indicated by the same prefixes as those previously referred to as being used in describing analogous divisions in the lamina of a leaf; thus a monosepalous calyx where the divisions are five, would be described as *five-partite*, *five-cleft*, or *five-toothed*, according to the depth of the divisions, and so on according to their number and depth. In a monosepalous calyx in which the union exists in a marked degree, the part where the sepals are united is called the *tube*, the free portion the *limb*, and the orifice of the tube the *throat* or *faux* (*figs.* 329 and 330).

Fig. 326.

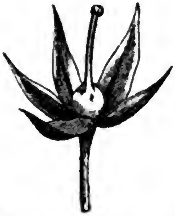


Fig. 327.

Fig. 328.

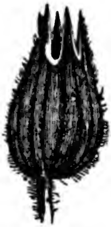


Fig. 326. Partite inferior calyx of the Pimpernel (*Anagallis*).—— *Fig.* 327. Cleft or fissured calyx of the Centaury (*Erythræa*).—— *Fig.* 328. Dentate or toothed calyx of the Campion (*Lychnis*).

If the union between the sepals is unequal, or the parts are of different sizes, or of irregular figures or forms, the calyx is said to be *irregular* (*fig.* 325); if, on the contrary, the parts are alike in figure or form, of the same size, and united so as to form a symmetrical body, it is *regular* (*fig.* 329). Some varieties of the irregular and also of the regular calyx have received special names. Thus in the Dead-nettle (*fig.* 330), the irregular calyx is said to be *labiate* or *bilabiate*, because the five sepals of which it is composed are united in such a manner as to form two lips. Of the regular forms of the monosepalous calyx a number are distinguished under the names of *tubular*, *campanulate*, *urceolate* (*fig.* 329), *globose*, &c. The application of these terms will be better shown when speaking of the corolla, in which similar forms occur, and in which they are usually more evident.

FIG. 329.

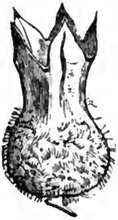


FIG. 330.

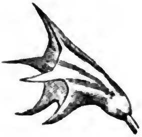


FIG. 331.

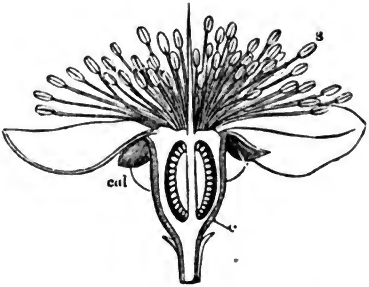


Fig. 329. Urceolate calyx of Henbane (*Hyoscyamus*).——*Fig.* 330. Irregular calyx of the Dead-nettle (*Lamium*).——*Fig.* 331. Vertical section of the flower of the Myrtle (*Myrtus communis*). *cal.* Tube of the calyx adherent to the ovary, *o.* *s.* Stamens.

The tube of a monosepalous calyx, or of that of a perianth, sometimes adheres more or less to the ovary, as in the Myrtle (*fig.* 331). When this takes place the calyx is said to be *adherent*, or, because it appears to arise from the summit of the ovary, it is termed *superior*; the ovary in such a case being then described as *inferior*. When the calyx is free, or quite distinct from the walls of the ovary, as in the Pimpernel (*fig.* 326), it is said to be *free*, *non-adherent*, or *inferior*; and the ovary is then termed *superior*.

When the calyx or perianth is thus adherent to the ovary, its limb presents various modifications: thus in the Iris it is *petaloid*; in the Quince, *foliaceous*; and in the Sunflower (*fig.* 334) *membranous*. In the Madder (*fig.* 332), it exists only in the form of a circular rim; while in the Ox-eye it is altogether absent (*fig.* 333). In the two latter cases the calyx is commonly described as *obsolete*. In many plants of the order Compositæ and the allied orders Dipsacaceæ and Valerianaceæ, the limb of the calyx is only developed in the form of a circle or tuft of bristles, hairs, or feathery processes, to which the name of *pappus* is given, and the calyx under such circumstances is said to be *pappose*. The pappus is further described as *feathery* or *plumose*, and *simple* or *pilose*; thus it is

FIG. 332.

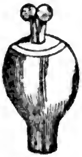


FIG. 333.

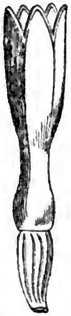


FIG. 334.

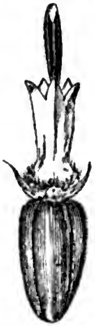


Fig. 332. Calyx of the Madder (*Rubia*), adherent to the ovary, with its limb reduced to a mere rim.——*Fig.* 333. One of the tubular florets of the Ox-eye (*Chrysanthemum*). The calyx is completely united to the ovary and presents no appearance of a limb.——*Fig.* 334. One of the florets of the Sunflower (*Helianthus*). The limb of the adherent calyx is membranous.

feathery, as in the Valerian (*fig.* 335), when each of its divisions is covered on the sides by little hair-like projections arranged like the barbs of a feather; and *pilose*, when the divisions have no marked projections from their sides, as in the Scabious (*fig.* 336). The pappus is also said to be *sessile* when it arises immediately from the tube of the adherent calyx, and thus apparently from the top of the ovary or fruit, as in the Valerian (*fig.* 335); and *stalked* if it is raised above the ovary or fruit, on a stalk, as in the Scabious (*fig.* 336).

FIG. 335.

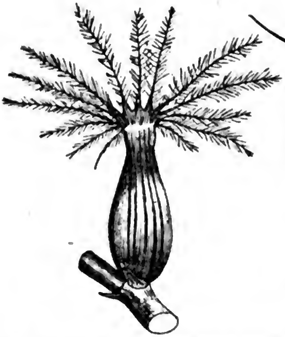


FIG. 336.

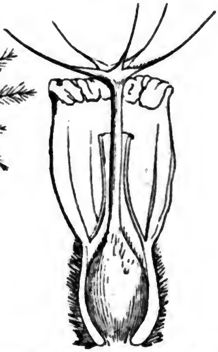


Fig. 335. Fruit of Valerian surmounted by a feathery sessile pappus. ——*Fig.* 336. Fruit of Scabious surmounted by a stalked pilose pappus.

APPENDAGES OF THE CALYX.—The calyx is also subject to various other irregularities. Thus in the Wallflower (*fig.* 21, *c*), and other plants of the Cruciferæ, the two lateral petals are expanded on one side at the base into little sacs, when they are termed *gibbous* or *saccate*. If the tube of a gamosepalous calyx becomes prolonged downwards so as to form a tube, or if one or more of the sepals form tubular prolongations downwards, the calyx or sepal is said to be *spurred*. Only one spur may be present, as in the Indian Cress (*fig.* 337, *c*), where the spur is formed by three sepals; or in the Larkspur, where it is formed by one; or each of the sepals may be spurred. In the Pelargonium, the spur, instead of being free from the pedicel, as in the above instances, is united to it.

On the outside of the calyx of some flowers, as in those of many plants of the Mallow (*fig.* 338), Pink (*fig.* 341, *b*), and Rose orders, there is placed a whorl of leaf-like organs which is considered by some botanists as an outer calyx, and to which the name of *epicalyx* has been accordingly given; but this outer whorl is evidently of the same nature as the *involucre* already noticed, and has been so described in this volume. (See page 179.)

FIG. 337.

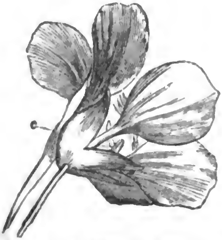


FIG. 338.

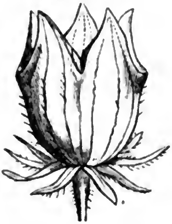


Fig. 337. Flower of the Indian Cress (*Tropæolum*). *c.* Spurred calyx.——*Fig.* 338. Calyx of *Hibiscus* surrounded by an epicalyx or involucre.

DURATION OF THE CALYX.—The duration of the calyx varies in different flowers. Thus it is *caducous* or *fugacious*, when it falls off when the flower expands, as in the Poppy. In the *Eschscholtzia* the calyx, which is caducous, separates from the hollow thalamus or pedicel, in the form of a funnel or the extinguisher of a candle, when it is said to be *calyptrate* or *operculate*. If the calyx falls off about the same time as the corolla, as in the Buttercup, it is then called *deciduous*; or, if it remains after the flowering is over, as in the Henbane, it is described as *persistent*. When the calyx is adherent or superior it is necessarily *persistent*, and forms a part of the fruit, as in the Quince (*fig.* 340). When it is persistent and assumes a shrivelled or withered appearance, as in the species of *Campanula*, it is *marcescent*; or, if it is persistent, and continues to grow after the flowering, so as to form a bladdery expansion round the fruit, as in the Winter Cherry, and other species of *Physalis* (*fig.* 339), it is termed *accrescent.*

FIG. 339.

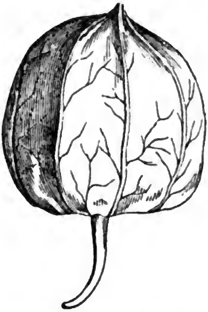


FIG. 340.

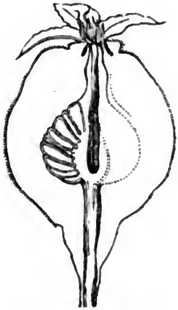


Fig. 339. Accrescent calyx of the Winter Cherry (*Physalis Alkekengi*). ——*Fig.* 340. Vertical section of the fruit of the Quince (*Pyrus Cydonia*), showing the tube of the calyx adherent to the matured carpels, and forming a part of the pericarp; the free portion, or limb, being foliaceous.

2. THE COROLLA.

The corolla is the inner envelope of the flower. It consists of one or more whorls of leafy organs, called *petals*; and is generally to be distinguished from the calyx by its coloured nature and more delicate structure. The corolla is usually the most showy and conspicuous part of the flower, and what in common language is termed *the flower*. In some rare cases, however, it is green like the calyx. Sometimes, again, there is a gradual transition from the sepals to the petals, as in the White Water-lily; and in the same plant there is also a similar transition from the petals to the stamens.

In structure the petals resemble sepals and leaves, being composed of parenchyma, supported by veins which are formed of spiral vessels, and usually reticulated. The whole petal is invested by epidermis, which is commonly destitute of stomata, but these organs may be sometimes found on the lower surface; hairs also occasionally occur. Petals are frequently narrowed below into a stalk-like portion, which is analogous to the petiole of a leaf, as in the Pink (*fig.* 342); the narrow portion is then termed the *unguis* or *claw*, *o*, and the expanded portion the *limb*, *l*, and the petal is said to be *unguiculate* or *clawed*.

The shape of petals, like those of sepals and leaves, is subject to great variation. Thus, they may be *linear*, *oblong*, *lanceolate*, *ovate*, &c. The condition of their margins also, the mode in which they are divided, and their terminations, are also indicated by the same terms as those previously described under similar heads in our chapter on Leaves. One term is occasionally used in describing the condition of the margins which has not been alluded to when speaking of leaves; thus the petals are said to be *fimbriated* or *fringed*, as in some species of *Dianthus* (*figs.* 341 and 342, *l*), when they present long thread-like processes at their margins.

Again, the petals may be either flat, as is usually the case, or *concave*, *tubular*, &c. In texture they are commonly soft and delicate, but sometimes they differ widely from this, and become thick and fleshy, as in the *Stapelia*; or dry and membranous, as in Heaths; or stiff and hard, as in *Xylopia*.

In describing their direction, we use the terms *erect*, *connivent*, *divergent*, and *reflexed*, in the same sense as already described when speaking of similar conditions of the sepals (page 209).

The petals also, like the sepals, may be either distinct or more or less united into one body. In the former case, the corolla is said to be *polypetalous* or *dialypetalous* (*figs.* 341–344); in the latter *monopetalous* or, more properly (page 210), *gamopetalous* (*figs.* 345–347).

FIG. 341.

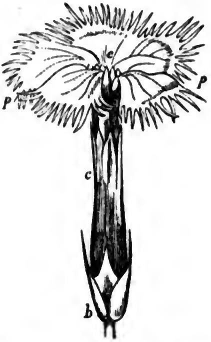


FIG. 342.

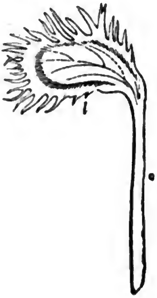


Fig. 341. The flower of a species of Pink (*Dianthus*). *b.* Bracts, forming an epicalyx or involucre. *c.* Calyx. *p, p.* Petals, the limbs of which are fringed at their margins. *e.* Stamens.——*Fig.* 342. One of the petals of the same flower. *o.* Claw or unguis. *l.* Limb, which is fimbriated or fringed at the margins.

FIG. 343.

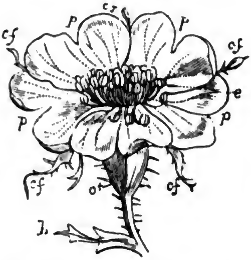


FIG. 344.

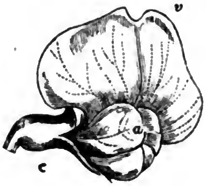


Fig. 343. Flower of the Rose. *b.* Bract. *ct.* Tube of the calyx. *cf, cf, cf, cf, cf.* Divisions of the calyx. *p, p, p, p, p.* Petals.——*Fig.* 344. The flower of the Sweet Pea (*Lathyrus odoratus*). *c.* Calyx. *v.* Vexillum. *a.* Alæ or wings. *car.* Carina or keel.

1. Polypetalous or Dialypetalous Corolla.—The

number of petals which enter into the composition of the corolla is indicated, as in the case of the polysepalous calyx by a prefix indicating that number.

When the petals are all of the same size, and of like form or figure, and arranged in a symmetrical manner, the corolla is termed *regular*, as in Rosaceous flowers (*fig.* 343); but when the petals vary in these particulars, as in the Pea and allied plants (*fig.* 344), it is said to be *irregular*. Some varieties of polypetalous corollas have received special names which we will now describe under the two heads of *regular* and *irregular*.

A. *Regular Polypetalous Corollas.*—Of these we may mention three varieties, viz. the *cruciform* or *cruciate*; the *caryophyllaceous*; and the *rosaceous*.

1. *Cruciform or Cruciate.*—This corolla gives the name to the natural order *Cruciferæ*; but it also occurs in other orders. It consists of four petals, usually with claws, as in the Wallflower (*fig.* 21, *p*), but sometimes without claws, as in the Celandine, and the whole arranged in the form of a Maltese cross.

2. *Caryophyllaceous.*—This consists of five petals, with long claws enclosed in the tube of the calyx, and with their limbs commonly placed at right angles to the claws, as in the Single Pink (*figs.* 341 and 342).

3. *Rosaceous.*—This is composed of five petals, without, or with very short, claws, and spreading in a regular manner, as in the Single Rose (*fig.* 343).

B. *Irregular Polypetalous Corollas.*—There are many varieties of irregular polypetalous corollas to which no particular names are applied; one, however, is of much importance, namely, the *Papilionaceous*. This derives its name from the fancied resemblance which it bears to a butterfly. It is composed of five petals (*fig.* 323), one of which is superior or posterior, and commonly larger than the others, and termed the *vexillum* or *standard* (*fig.* 344, *v*); two inferior or anterior, which are usually more or less united and form a somewhat boat-shaped cavity, *car*, called the *keel* or *carina*; and two lateral, *a*, called the *wings* or *alæ*.

2. MONOPETALOUS OR GAMOPETALOUS COROLLA.—When the petals unite so as to form a monopetalous corolla, various terms are used, as in the case of the monosepalous calyx, to indicate the degrees of adhesion: thus the corolla may be *partite*, *cleft*, *toothed*, or *entire*, the terms being employed in the same sense as before explained (page 211), as with the calyx. The part also where union has taken place is in like manner called the *tube*, *t*; the free portion, the *limb*, *l*; and the orifice of the tube, the *throat* or *faux* (*fig*. 345).

FIG. 345.

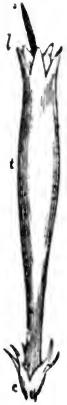


FIG. 346.

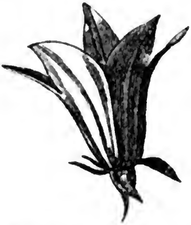


FIG. 347.

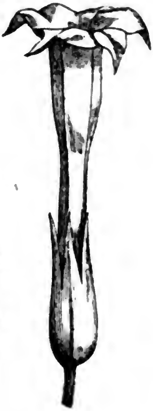


Fig. 345. Flower of *Spigelia marylandica*. *c*. Calyx. *t*. Tubular corolla. *l*. Limb of the corolla. *s*. Summit of the style and stigmas.——*Fig*. 346. Flower of the Harebell (*Campanula rotundifolia*), showing a campanulate corolla.——*Fig*. 347. Flower of the Tobacco Plant (*Nicotiana Tabacum*), with infundibuliform corolla.

The monopetalous corolla, like the monosepalous calyx, is *regular* when its parts are of the same size, and of like figure or form, and united so as to form a symmetrical body (*figs*. 345–350); or, if these conditions are not complied with, it is *irregular* (*figs*. 351–356). Some varieties of both regular and irregular monopetalous corollas have received special names, as follows:—

A. *Regular Monopetalous Corollas.*—Of these we may describe the following:—

Tubular (*fig.* 345), where the form is nearly cylindrical throughout, as in the central florets of many Compositæ, as the Ox-eye and Sunflower (*figs.* 333 and 334); *campanulate* or *bell-shaped*, when the corolla is rounded at the base, and gradually enlarged upwards to the summit, so as to resemble a bell in form, as in the Harebell (*fig.* 346); *infundibuliform* or *funnel-shaped*, where the form of the corolla is that of an inverted cone, like a funnel, as in the Tobacco (*fig.* 347); *hypocrateriform* or *salver-shaped* (*fig.* 348), when the tube is long and narrow, and the limb placed at right angles to it, as in the Primrose; *rotate* or *wheel-shaped*, when the tube is short, and the limb at right angles to it, as in Forget-me-not (*fig.* 349); *urceolate* or *urn-shaped*, when the corolla is swollen in the middle, and contracted at both the base and apex, as in the Purple Heath (*fig.* 350).

FIG. 348.

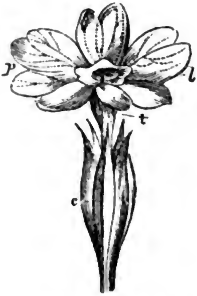


FIG. 349.

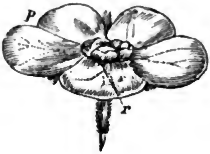


FIG. 350.

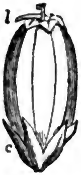


Fig. 348. Flower of a species of *Primula*. *c.* Calyx, within which is seen a hypocrateriform corolla, *p.* *t.* Tube of the corolla. *l.* Limb.——*Fig.* 349. Flower of the Forget-me-not (*Myosotis palustris*). *p.* Rotate corolla. *r.* Scales projecting from its limb close to the throat.——*Fig.* 350. Flower of a species of Heath (*Erica*). *c.* Calyx, within which is an urceolate corolla, *t*, *l*.

B. *Irregular Monopetalous Corollas.*—Of these we shall describe the following:—

1. *Labiate or Bilabiate.*—When the parts of a corolla are so united that the limb is divided into two portions which are placed superiorly and inferiorly, the upper portion overhanging the lower, and each portion so arranged as not to close the orifice of the tube, so that the whole resembles in some degree the lips and open mouth of an animal (*figs.* 351–353), the corolla is termed *labiate* or *bilabiate.* The upper lip is composed of two petals, which are either completely united, as in the White Dead-nettle (*fig.* 351), or more or less divided, as in the Germander (*fig.* 352); and the lower lip, of three petals, which are also either entire as in the Rosemary, or bifid as in some species of *Lamium*, or trifid as in *Galeobdolon* (*fig.* 353). When a labiate corolla has its upper lip much arched, as in the White Dead-nettle (*fig.* 351), it is frequently termed *ringent* or *gaping.* The labiate corolla gives the name to the natural order Labiatæ, in the plants belonging to which it is of almost universal occurrence.

FIG. 351.

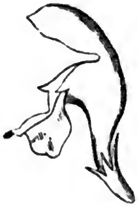


FIG. 352.

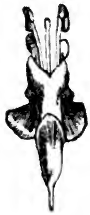


FIG. 353.

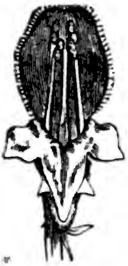


Fig. 351. Ringent or gaping corolla of Dead-nettle (*Lamium album*), showing the entire upper lip.——*Fig.* 352. Back view of the flower of a species of *Teucrium*, showing the bifid upper lip of the corolla. ——*Fig.* 353. Front view of the labiate corolla of *Galeobdolon*, with trifid lower lip.

It is found also in certain plants belonging to some other orders.

2. *Personate or Masked.*—This form of corolla resembles the labiate in being divided into two lips, but it is distinguished by the lower lip being approximated to the upper, so as to close the orifice of the tube or throat. This closing of the throat is caused by a projection of the lower lip called the *palate* (*fig.* 354, *l*). Examples occur in the Snapdragon and Toadflax.

3. *Ligulate or Strap-shaped.*—If what otherwise would be a tubular corolla is partly split open on one side, so as to become flattened like a strap above (*fig.* 355), it is called *ligulate* or *strap-shaped.* This kind of corolla is of common occurrence in the florets of the Compositæ: its apex frequently presents five teeth indicating the component petals (*fig.* 355).

FIG. 354.

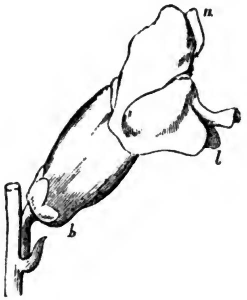


FIG. 355.

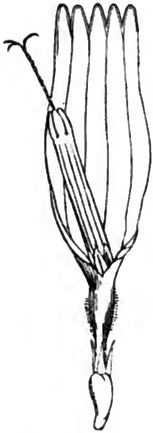


Fig. 354. Personate corolla of Snapdragon (*Antirrhinum*). *l.* Lower lip. *u.* Upper lip. *b.* Gibbous base.——*Fig.* 355. Ligulate corolla of a composite flower, with five teeth at its apex.

APPENDAGES OF THE COROLLA.—The corolla, like the calyx, whether polypetalous or monopetalous, is subject to various irregularities, arising from the expansion or growing outwards of one or more of the petals, or tube of a monopetalous corolla, into processes of different kinds. Thus in the Snapdragon (*fig.* 354 *b*), and Valerian (*fig.* 400), the lower part of the tube of the corolla becomes dilated on one side, so as to form a little bag or sac: it is then termed *saccate* or *gibbous*. At other times, one or more of the petals (*fig.* 357), or the tube of a monopetalous corolla (*fig.* 356), becomes prolonged downwards and forms a *spur*, in which case the petal or corolla is described as *spurred*. Only one spur may be present as in the Heartsease, or each of the petals may be spurred as in the Columbine (*fig.* 357).

FIG. 356.

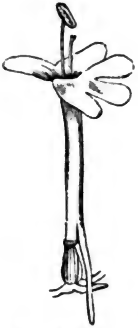


FIG. 357.

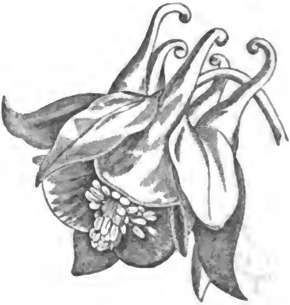


Fig. 356. Flower of Red Valerian (*Centranthus*). The corolla is spurred at its base.——*Fig.* 357. Flower of Columbine (*Aquilegia vulgaris*), with each of its petals spurred.

On the inner surface of the petals of many flowers we may frequently observe appendages of different kinds in the form of scales or hair-like processes of various natures. Such appendages may be well seen in the Lychnis (*fig.* 359, *a*), and Grass of Parnassus (*fig.* 358). Similar scales may be also frequently noticed in monopetalous corollas near the throat, as in many Boraginaceous plants, for instance, the Forget-me-not (*fig.* 349, *r*). Sometimes these scales become more or less coherent and form a cup-shaped process, as in the perianth of the Daffodil (*fig.* 360) and other species of *Narcissus*; to this the term *corona* is commonly applied, and the corolla is then said to be *crowned*. The beautiful fringes on the corolla of the Passion-flower are of an analogous nature.

FIG. 358.

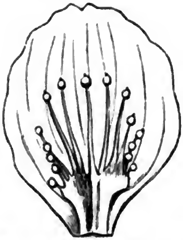


Fig. 358. A petal of the Grass of Parnassus (*Parnassia palustris*) bearing a fringed scale at its base.

DURATION OF THE COROLLA.—The duration of the corolla varies like that of the calyx, but it is almost always more fugitive than it. It is *caducous* if it falls as the flower opens, as in the

FIG. 359

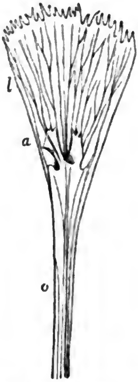


FIG. 360.

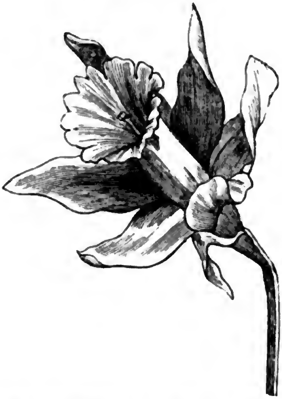


Fig. 359. A petal of a species of *Lychnis*. *o*. Claw. *l*. Limb. *a*. Scaly appendages.——*Fig.* 360. Flower of Daffodil (*Narcissus Pseudo-narcissus*). The cup or bell-shaped process towards the centre is termed a corona.

Grape-vine; but commonly it is *deciduous*, or falls off soon after the opening of the flower. In rare instances it is *persistent*, in which case it usually becomes dry and shrivelled, as in Heaths and the species of *Campanula*, when it is said to be *marcescent*.

Section 4. THE ESSENTIAL ORGANS OF REPRODUCTION.

THE andrœcium and gynœcium, which form the two inner whorls of the flower, are called the essential organs of reproduction, because the action of both is necessary for the production of perfect seed.

Flowers which possess both these organs are called *hermaphrodite* or *bisexual* (*fig.* 373); when only one is present, they are *unisexual* or *diclinous*, as in the species of *Carex* (*fig.* 361), and *Salix* (*figs.* 294 and 295). The flower is also then further described as staminate (*figs.* 294 and 361) when it contains only a stamen or stamens; and carpellary or pistillate, when it has only a carpel or carpels (*fig.* 295). When a flower possesses neither andrœcium nor gynœcium, as is sometimes the case with the outer florets of the capitula of the Compositæ, it is said to be *neuter*. When the flowers are unisexual both staminate and pistillate flowers may be borne upon the same plant, as in the Cuckoo-pint and species of *Carex*, in which case the plant is stated to be *monœcious*; or upon different plants of the same species, as in Willows, when the plant is said to be *diœcious*.

FIG. 361.

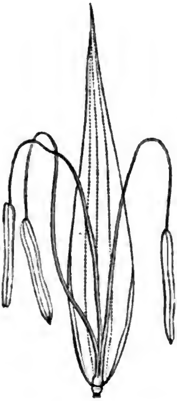


Fig. 361. Unisexual staminate flower of a species of *Carex*. The filaments are long and capillary, and the anthers pendulous and innate.

In some cases, as in many Palms, staminate, pistillate and bisexual flowers are situated upon the same individual, and then the plant is called *polygamous.*

1. THE ANDRŒCIUM.

The andrœcium or male system of Flowering plants is composed of one or more parts termed *Stamens.* Each stamen consists generally of a stalk, called the *filament* (*fig.* 23, *f*); and of a little bag or case, *a*, which is the representative of a blade of a leaf, termed the *anther*, and which contains a powdery, or more rarely waxy, matter, called the pollen, *p*. The only essential part of the stamen, however, is the anther with its contained pollen; but in rare cases the pollen is absent, and as the stamen cannot then perform its special functions, it is said to be *abortive* or *sterile*; under other circumstances it is *fertile.* It not unfrequently happens that flowers contain filaments without anthers, in which case these structures are termed *staminodes.* When, as is rarely the case, the filament is absent, as in the Cuckoo-pint (*fig.* 362), the anther is described as *sessile.*

1. THE FILAMENT.—In its structure the filament, which corresponds to the petiole of a leaf, consists, 1st, of a central usually unbranched bundle of spiral vessels; and 2nd, of parenchymatous tissue which surrounds the bundle of spiral vessels, and which is itself covered by thin epidermal tissue. The epidermis occasionally presents stomata and hairs; and these hairs are sometimes coloured, as in the Spiderwort.

The filament varies in form, length, colour, and other particulars; a few of the more important modifications of which will be now alluded to. Thus, as its name implies, the filament is usually found in the form of a little thread-like or cylindrical prolongation which generally tapers in an almost imperceptible manner from the base to the apex, when it is described as *fili-*

form, as in the Rose; or if it is very slender, as in most Grasses, it is *capillary* (*fig.* 363). At other times the filament becomes enlarged, and then becomes *clavate*, or *club-shaped*, &c. In other cases it is flattened in various ways, either at the base only, as in species of *Campanula* (*fig.* 364); or the whole of the filament is flattened, and then it frequently assumes the appearance of a petal, when it is described as *petaloid*, as in the Water-lily (*fig.* 375). Sometimes, again, it is *toothed*, or *forked*, or furnished with various appendages, as in the Borage (*fig.* 365, *a*), in which case it is said to be *appendiculate.*

FIG. 362.

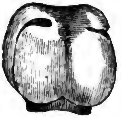


FIG. 363.

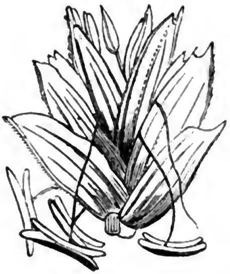


FIG. 364.

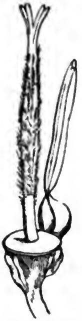


Fig. 362. Stamen of the Cuckoo-pint (*Arum maculatum*), consisting simply of an anther which is sessile upon the thalamus.——*Fig.* 363. A locusta of Wheat (*Triticum*) consisting of several flowers, the stamens of which have very long capillary filaments, and versatile pendulous anthers. The anthers are bifurcated at each extremity, and resemble somewhat the letter *x* in form.——*Fig.* 364. Pistil of a species of *Campanula*, with a solitary stamen, the filament of which is flattened at its base.

The length of the filament also varies much. Thus in the Borage (*fig.* 365, *f*), and plants generally of the order Boraginaceæ (*fig.* 366), the filaments are very short; while in Sedges (*fig.* 361), they are usually very long.

In *colour* the filaments are generally white, but at other times they assume vivid tints; thus in the Spiderwort they are blue, in various species of *Ranunculus* yellow, in some Poppies black, in Fuchsias red, &c.

In *direction* the filaments, and consequently the stamens, are either *erect*, *incurved*, *recurved*, *pendulous*, &c.; these terms being used in their ordinary acceptation. But when the filaments are all turned towards one side of the flower, as in the Horsechestnut, they are said to be *declinate*. Generally speaking, their direction is nearly straight, but in other cases they are more or less bent towards their upper extremity. This appearance, however, sometimes arises from the presence of an articulation at the point where the angle is produced, as in *Euphorbia* (*fig.* 367, *a*). In such a case, or whenever an articulation exists on the apparent filament, this is not to be considered as a true filament, but to consist in reality of a flower-stalk supporting a single stamen, which here represents the flower.

FIG. 365.

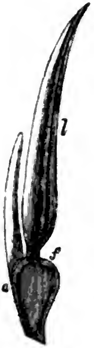


FIG. 366.

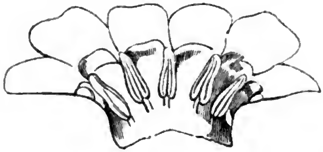


FIG. 367.

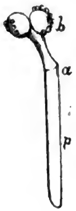


Fig. 365. A stamen of the Borage (*Borago officinalis*). *f.* Filament. *a.* Curved appendage to the filament. *l.* Anther.——*Fig.* 366. Corolla of *Myosotis* or Forget-me-not (Boraginaceæ), laid open. There are five stamens with very short filaments attached to the corolla and included within its tube.——*Fig.* 367. Male flower of *Euphorbia*, consisting of a solitary stamen, *b*, without any floral envelopes, hence it is said to be achlamydeous. The anther is two-lobed and the connective very small. *a.* Articulation, indicating the point of union of the true filament and peduncle, *p*.

The filament varies also in duration, but it usually falls off after the influence of the pollen has been communicated to the carpel, or, is *deciduous*. But in rare cases, as in the species of *Campanula*, the filament is persistent, and remains attached to the ovary in a withered condition.

FIG. 368.

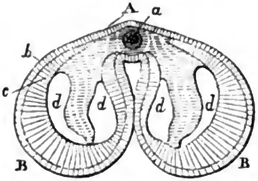


Fig. 368. Transverse section of a young anther of *Neottia picta*. From Schleiden. A. Back of the anther, to which the connective is attached. B, B. The two lobes of the anther. *a*. Vascular bundle of the connective. *b*. Epidermal layer or exothecium. *c*. Layer of fibrous cells which is commonly termed the endothecium, and which is the mesothecium of the anther in an earlier stage of development. *d, d, d, d*. The four loculi or cells of the anther. Each lobe is seen to be divided into two loculi by a septum or partition.

2. THE ANTHER.—*Its Parts.*—The different parts of which the anther is composed may be best seen by making a transverse section, as shown in *fig*. 368. Thus here we observe two parallel *lobes*, B, B, separated by a portion, A, *a*, called the *connective*, to which the filament is attached. Each lobe is divided into two cavities, *d d d d*, by a septum, which passes from the connective to the walls of the anther. The cavities thus formed in the lobes of the anther are called *cells* or *loculi*. All anthers in an early stage of development possess *four loculi*, and this is considered the normal state. When a fully-developed anther exhibits such a structure, it is *four-celled* or *quadrilocular* (*figs*. 369 and 386); or when, as is far more commonly the case, the partitions separating the two loculi of each anther-lobe become absorbed, it is *two-celled* or *bilocular* (*fig*. 23, *a*). In rare cases, the anther is *unilocular* or *one-celled*, as in Milkwort (*fig*. 370), and Lady's Mantle (*fig*. 371): this arises, either from the abortion of one lobe of the anther, and the absorption of the septum between the two cells of the lobe that is left; or by the destruction of the partition wall of the two lobes

as well as of the septa between the cells of each lobe. In some plants, again, as in many species of *Salvia*, the connective becomes elongated into a kind of stalk, each end of which bears an anther lobe (*fig.* 372), in which case there appear to be two *unilocular* or *one-celled* anthers. When this occurs, one lobe only, *lf*, contains pollen, the other, *ls*, is sterile.

That surface of the anther to which the connective

FIG. 369.

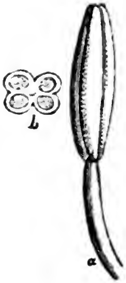


FIG. 370.

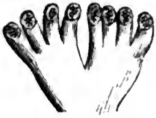


FIG. 371.

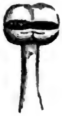


FIG. 372.

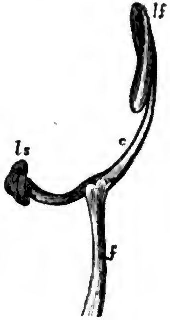


Fig. 369. Four-celled anther of the Flowering Rush (*Butomus umbellatus*). *a.* Filament bearing an entire anther. *b.* Section of the anther with its four cells.——*Fig.* 370. Andrœcium of Milkwort (*Polygala*), with eight one-celled anthers dehiscing at their apex.——*Fig.* 371. One of the stamens of the Lady's Mantle (*Alchemilla*). The anther is one-celled, and dehisces transversely.——*Fig.* 372. Stamen of the Sage (*Salvia*). *f.* Filament. *c.* Connective, bearing at one end a cell, *lf*, containing pollen, which is then said to be fertile; and at the other end a sterile cell, *ls*, or one without pollen.

is attached is called the *back* (*fig.* 368, A, *a*), and the opposite surface is the *face*. The latter always presents a more or less grooved appearance (*figs.* 368 and 373, *c*), indicating the point of junction of the two lobes. Each lobe also commonly presents a more or less evident furrow (*fig.* 373, *b*), indicating the point at which the mature anther will open to discharge the pollen;

this furrow is termed the *suture*. By these furrows the face of the anther may be generally distinguished from the back, which is commonly smooth (*fig.* 368, A), and has moreover the filament attached to it. The face is generally turned towards the gynœcium, as in the Water-lily (*fig.* 375), and Vine (*fig.* 373), in which case the anther is called *introrse*; but in some instances, as in the Iris, the face is directed towards the petals, when it is *extrorse*.

FIG. 373.

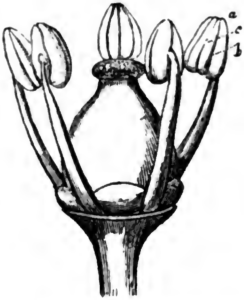


FIG. 374.

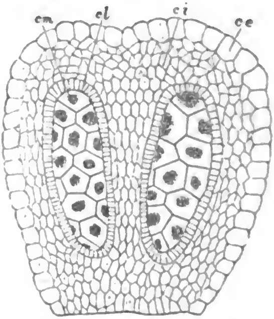


Fig. 373. The Essential Organs of Reproduction of the Vine (*Vitis vinifera*). *a.* Anther. *c.* Furrow in its face which is turned towards the gynœcium. *b.* Suture or line of dehiscence. The anther is introrse.——*Fig.* 374. Vertical section of a loculus or cell of a young anther of the Melon. *ce.* Epidermal layer constituting the exothecium or outer covering of the anther. *ci.* The parenchymatous cells which ultimately form the *mesothecium*. *cm.* The central masses of cells, two of which are placed in each half or lobe of the anther, which contain pollen, and are termed parent or mother cells. These cells are surrounded by a special layer of cells, *cl*, or endothecium. From Le Maout.

Its Development and Structure.—When first formed the anther consists of parenchymatous cells of about the same size and form; but ultimately each lobe presents two central masses of cells which are termed parent or mother-cells (page 243), from being devoted to the formation of the pollen (*fig.* 374, *cm*), and over which we have three distinct layers of cells. The inner one, *cl*

—that is, the layer immediately enclosing each central mass—is called the *endothecium*; it is formed of but a single row of delicate cells; and commonly disappears as the pollen becomes matured, but it is persistent in those anthers which have porous dehiscence. The layer, *ci*, immediately outside the endothecium, is termed the *mesothecium*. It is a permanent layer, and consists of one or more rows of cells, some of which, except in the case of anthers opening by pores, contain spiral, reticulated, or annularly arranged fibres. The third, or external layer, *ce*, is of an epidermal nature, and is called the *exothecium*, and upon which stomata are frequently found.

FIG. 375.

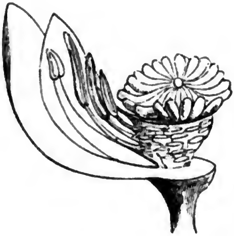


FIG. 376.

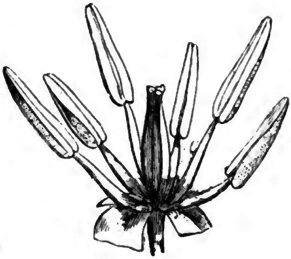


Fig. 375. A portion of the flower of the White Water-Lily (*Nymphæa alba*), consisting of a gynœcium invested by a large fleshy disk prolonged from the thalamus below. The pistil is surrounded by some stamens which have petaloid filaments and adnate introrse anthers; and by two petals.——*Fig.* 376. Gynœcium and andrœcium of the Tulip. The anthers dehisce longitudinally.

The anther in its mature form presents therefore, in nearly all cases, but two coats, as shown in *fig.* 368, that is, an *exothecium*, or outer coat, *b*, and an *endothecium*, or inner coat, *c*, which corresponds in structure to the mesothecium of the immature anther. The connective, as a general rule, has a similar structure to the filament.

Attachment of the Filament to the Anther.—There are three modes of attachment which are distinguished by special names. Thus: 1st, the anther is said to be *adnate* or *dorsifixed* when its back is attached throughout its whole length to the filament, or to its continuation called the connective, as in the Magnolia (*fig.* 378); 2nd, it is *innate* or *basifixed* when the filament is only attached to its base, and firmly adherent, as in the species of *Carex* (*fig.* 361); and 3rd, it is *versatile*, when the filament is only attached by a point to about the middle of the back of the connective, so that the anther swings upon it, as in Grasses generally (*fig.* 363).

FIG. 377.

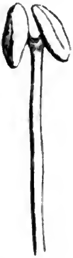


FIG. 378.

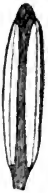


FIG. 379.

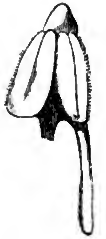


FIG. 380.

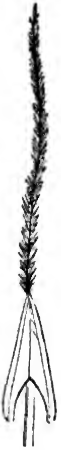


Fig. 377. A stamen of the Lime (*Tilia*), showing the large connective separating the lobes of the anther.——*Fig.* 378. An inside view of a stamen of *Magnolia glauca*, showing the adnate anther and prolonged connective.——*Fig.* 379. Two stamens of the Heartsease (*Viola tricolor*). The connective of one of them is prolonged downwards in the form of a spur.——*Fig.* 380. Sagittate anther lobes of the Oleander (*Nerium Oleander*), and the prolonged feathery connective.

Connective.—The relations of the anther to the filament, as well as its lobes to each other, are much influenced by the appearance and size of the connective. Thus in all adnate anthers the connective is large, and the lobes generally more or less parallel to each other throughout their whole length (*fig.* 378). In other cases the connective is very small, or altogether wanting, as in species of *Euphorbia* (*fig.* 367), so that the lobes of the anther are then immediately in contact at their base. In the Lime the connective completely separates the two lobes of the anther (*fig.* 377). In the Sage (*fig.* 372) and other species of *Salvia*, the connective forms a long stalk-like body placed horizontally on the top of the filament, one end of which bears an anther lobe, *lf*, containing pollen, the other merely a petaloid plate or abortive anther lobe, *ls*; it is then said to be *distractile.* Sometimes the connective is prolonged beyond the lobes of the anther; either as a little rounded or tapering expansion, as in the Magnolia (*fig.* 378), or as a long feathery process, as in the Oleander (*fig.* 380), or in various other ways. At other times again, it is prolonged downwards and backwards as a kind of spur, as in the Heartsease (*fig.* 379). Anthers with such appendages are termed *appendiculate.*

The lobes of the anther also, like the connective, frequently present appendages of various kinds. Thus in the *Erica cinerea* they have a flattened leafy body at their base (*fig.* 382, *a*); at other times the surface of the anther presents projections in the form of pointed bodies (*fig.* 383, *a*), or warts, &c. Such anthers, like those which present appendages from the connective, are termed *appendiculate.*

Forms of the Anther Lobes and Anther.—The lobes of the anther assume a variety of forms, as *rounded*, *oval*, *linear*, *sinuous* as in the Gourd tribe (*fig.* 381, *l*); and at other times they are pointed, or prolonged in various ways. These and other forms which they assume, combined with those of the connective, determine that of the anther, which may be *oval*, *oblong*, &c.; or *forked*, or *sagittate* (*fig.* 380), &c. In the Grasses the anthers are bifurcate at each extremity (*fig.* 363), so as to resemble somewhat the letter *x* in form.

The anther when young is of a greenish hue, but when fully matured it is usually yellow. There are, however, many exceptions to this: thus it is dark purple or black in many Poppies, orange in *Eschscholtzia*, purple in the Tulip, red in the Peach, &c.

Dehiscence of the Anther.—When the anthers are perfectly ripe they open and discharge the contained pollen (*figs.* 23, *p*, and 376); this act is called the *dehiscence* of the anther.

FIG. 381.

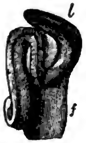


FIG. 382.

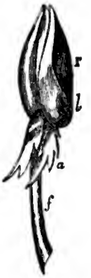


FIG. 383.

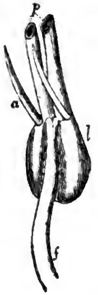


FIG. 384.

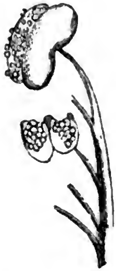


Fig. 381. The sinuous anther lobes, *l*, attached to the filament, *f*, of the common Bryony (*Bryonia dioica*).——*Fig.* 382. Appendiculate anther attached to filament, *f*, of the Fine-leaved Heath (*Erica cinerea*). *a.* Appendage. *l.* Lobes. *r.* Lateral slit where dehiscence takes place.——*Fig.* 383. Bifurcate or forked anther of *Vaccinium uliginosum* attached to filament, *f*. *l.* Anther lobes. *a.* Appendages. *p.* Points of the anther lobes where dehiscence takes place.——*Fig.* 384. Stamen of the Mallow (*Malva*), the anther of which has an apparently transverse dehiscence.

The dehiscence of the anther may take place in four different ways, which are respectively called *longitudinal*, *transverse*, *porous*, and *valvular*.—*Longitudinal* or *sutural*: this, the usual mode of dehiscence, consists in the opening of each anther lobe from the base to the apex in a longitudinal direction along the line of suture, as in the Tulip (*fig.* 376).—*Transverse*: this kind of dehiscence consists in the splitting open of the anther transversely, that is, from the connective to the side, and mostly occurs in one-celled anthers, as in those of *Alchemilla* (*fig.* 371). It sometimes happens, as in the Mallow (*fig.* 384), and other plants of the order Malvaceæ, that by the enlargement of the connective the loculus of a one-celled anther is placed horizontally instead of vertically, in which case the dehiscence when it takes place in the line of the suture would be apparently transverse, although really longitudinal; but in descriptive botany such anthers, like the former, are

FIG. 385.

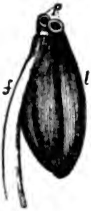


FIG. 386.

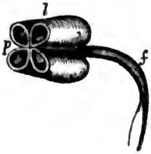


FIG. 387.

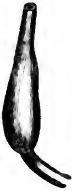


FIG. 388.

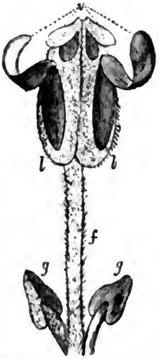


Fig. 385. Anther of the *Pyrola rotundifolia*, suspended from the filament, *f.* *l.* Loculi opening by two pores, *p.*——*Fig.* 386. Quadrilocular anther of *Poranthera*, attached to filament, *f.* *l.* Loculi opening by pores, *p.* ——*Fig.* 387. Anther of *Tetratheca juncea*, opening by a single pore at the apex. The above figures are from Jussieu.——*Fig.* 388. Stamen of a species of *Laurus*. *f.* Filament, with two glands, *g*, *g*, at its base. *l*, *l*. Loculi, of which there are four. *v.* Valves.

said to dehisce transversely.—*Porous* or *Apical*: this is a mere modification of longitudinal dehiscence. It is formed by the opening of the anther lobes being arrested at an early period so as only to produce pores or short slits. The pores or slits may be either situated at the apex, as in the Milkwort (*fig.* 370); or laterally, as in the Heaths (*fig.* 382, *r*). There may be either two pores as is usually the case (*fig.* 385, *p*), or four (*fig.* 386, *p*), or many as in the Mistletoe, or only one (*fig.*

387).—*Valvular* or *Opercular*: this name is applied when the whole or portions of the face of the anther open like trap-doors, which are attached at the top and turn back as if on a hinge. In the Barberry (*fig.* 413) there are but two such valves or lids; while in plants belonging to the Laurel order there are two or four such lids (*fig.* 388, *v*), according as the anthers have two or four cells.

THE STAMENS GENERALLY, OR THE ANDRŒCIUM.—Before describing the pollen or contents of the anther, we shall take a general view of the stamens as regards their relations to each other, and to the other whorls of the flower. This part of our subject will be treated of under four heads, namely:—1. Number, 2. Insertion or Position, 3. Union, 4. Relative length.

1. *Number.*—The stamens may be equal or unequal in number to the sepals and petals, and corresponding terms are used accordingly. When equal in number, as in the Primrose, they are also technically said to be *isostemonous*; and when unequal, as in the Red Valerian (*fig.* 356), the flower is *anisostemonous.* The flower also receives different names according to the actual number of stamens it contains, without reference to the number of parts in the outer whorls. This number is indicated by one of the Greek numerals prefixed to the word *androus*, which means male, in reference to the function of the stamen. Thus, a flower having one stamen is *monandrous*, two *diandrous*, three *triandrous*, four *tetrandrous*, and so on.

2. *Insertion or Position.*—When the stamens are free from the calyx and pistil, and arise directly from the thalamus below the latter organ, as in the Crowfoot (*fig.* 389) and Vine (*fig.* 373), they are said to be *hypogynous*, which signifies under the female or pistil. When the stamens are attached to the corolla, as in the Primrose (*fig.* 390), they are *epipetalous*; when they adhere to the calyx more or less, so that their position becomes somewhat lateral to the pistil instead

of below it, as in the Cherry (*fig.* 391), they are said to be *perigynous.* When the calyx is adherent to the ovary so that it appears to rise from its apex, the intermediate stamens and corolla are necessarily placed on

FIG. 389.

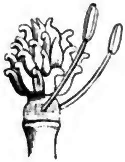


FIG. 390.

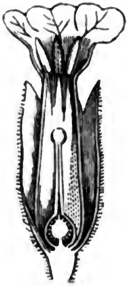


Fig. 389. Apocarpous pistil of the Crowfoot (*Ranunculus*), with two stamens arising from the thalamus below it, or hypogynous. ——*Fig.* 390. Vertical section of a flower of the Primrose (*Primula*), showing epipetalous stamens. The pistil in the centre has an ovary with a free central placenta, one style, and a capitate stigma.

FIG. 391.

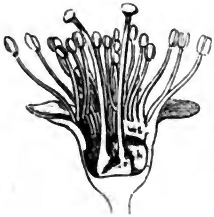


FIG. 392.

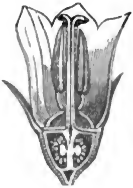


FIG. 393.

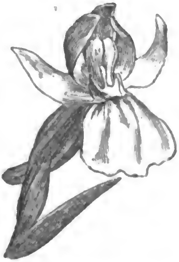


Fig. 391. Vertical section of the flower of the Cherry, showing the perigynous stamens surrounding the pistil.——*Fig.* 392. Vertical section of the flower of a species of *Campanula*, with epigynous stamens.——*Fig.* 393. Flower of *Orchis mascula.* The column in the centre is formed by the union of the stamens and style.

its summit, and are said to be *epigynous*, as in the species of *Campanula* (*fig.* 392). It sometimes happens that the stamens not only arise from the top of the ovary, as in the epigynous form of insertion, but the upper part of the stamen or stamens and style become completely united also, and thus form a column in the centre of the flower, as in the Orchis (*fig.* 393), and Birthworth (*fig.* 394); this column is then termed the *gynostemium*, and the flowers are said to be *gynandrous*.

FIG. 394.

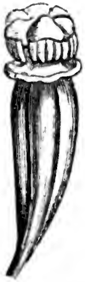


FIG. 395.

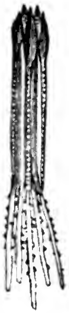


FIG. 396.

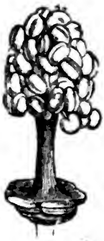


Fig. 394. The pistil and stamens of Birthwort (*Aristolochia*). The ovary is seen below, and the stamens above united into a column with the style.——*Fig.* 395. Syngenesious anthers of a species of Thistle (*Carduus*).——*Fig.* 396. Monadelphous stamens of a species of Mallow (*Malva*).

3. *Union or Cohesion.*—When the stamens are perfectly free and separate from each other, as in the Vine (*fig.* 373), they are said to be *free* or *distinct*; when united, as in the Mallow (*fig.* 396), they are *coherent* or *connate*. In the latter case the union may take place either by their anthers, or by their filaments, or by both anthers and filaments. When the anthers unite, the stamens are termed *syngenesious* or *synantherous* (*fig.* 395), as in the Compositæ. When the anthers thus unite, the filaments are commonly, though

not always, distinct. When union occurs between the stamens by their filaments, this may take place in one or more bundles, the number being indicated by a Greek numeral prefixed to the word *adelphous*, which signifies *brotherhood.* Thus, when all the filaments unite together and form one bundle, as in the Mallow (*fig.* 396), and Wood Sorrel, the stamens are said to be *monadelphous.* When the filaments unite so as to form two bundles, the stamens are termed *diadelphous*, as in the Pea (*fig.* 397), in which case the number of filaments in each bundle may be equal as in the Milkwort (*fig.* 370), or unequal as in the Pea (*fig.* 397), where there are ten stamens, the filaments of nine of them being united to form one bundle, while the other filament remains free. When the stamens are united by their filaments into three bundles, they are termed *triadelphous*, as in most species of St. John's Wort (*fig.* 399); and when in more than three, *polyadelphous*, as in the Orange (*fig.* 398); or the latter term is applied in all cases where there are more than two bundles of stamens, in which sense it was used by Linnæus.

FIG. 397.

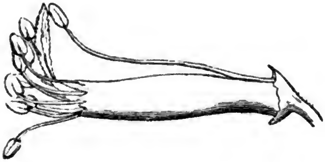


FIG. 398.

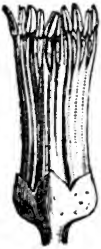


Fig. 397. Diadelphous stamens of the Sweet Pea (*Lathyrus odoratus*), surrounding the pistil. There are ten stamens, nine of which are united and one free.——*Fig.* 398. Flower of the Orange, divested of its corolla to show the polyadelphous stamens.

The union of the filaments in the above cases may either take place more or less completely, and thus form a tube of varying heights, as in the Mallow (*fig.* 396), or the union may only take place at the base, as in most species of *Hypericum.* When the union takes place so as to form a tube or column, the term *androphore* has been applied to such a column.

4. *Relative Length.*—In the first place, when the stamens are shorter than the tube of the corolla so as to be enclosed within it, as in the Forget-me-not (*fig.* 366), they are said to be *included*; and when the stamens are longer than the tube of the corolla so as to extend beyond it, as in the Valerian (*fig.* 400), they are *exserted* or *protruding.*

FIG. 399.

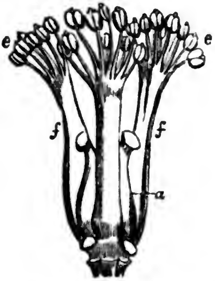


FIG. 400.

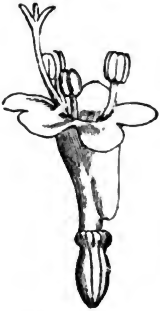


Fig. 399. The pistil, *a*, of *Hypericum ægyptiacum*, surrounded by the stamens, *e*, *e*, which are united by their filaments, *f*, *f*, into three bundles.——*Fig.* 400. Flower of Valerian, showing the stamens prolonged beyond the tube of the corolla, or exserted. The corolla is gibbous at the base.

Secondly, as regards themselves the stamens may be as nearly as possible of the same length, or more or less unequal. This inequality may be altogether irregular again, following no definite rule, or take place in a definite and regular manner. Thus in the case of such flowers as the Willow Herb, where the number of stamens is double that of the petals, the stamens alternating with the petals are almost always longer than those opposite to them. When the stamens are of unequal length in the same flower, or in different flowers of the same species, as in the Primrose, they are said to be *dimorphic*, and will be afterwards alluded to in speaking of fertilisation.

When there is a definite relation existing between the long and short stamens with respect to number, certain names are applied to indicate such forms of regularity. Thus in the Wallflower (*fig.* 22), there are six stamens to the flower, of which four are long and arranged in pairs opposite to each other, and alternating with two solitary shorter ones; to such an arrangement we apply the term *tetradynamous*. When there are but four stamens, of which two are long and two short, as in Labiate plants generally (*fig.* 353), and in the Foxglove (*fig.* 401), they are said to be *didynamous*.

FIG. 401.

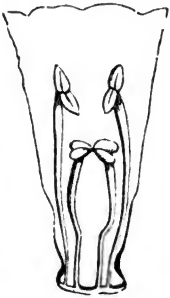


Fig. 401. Didynamous stamens of the Foxglove (*Digitalis purpurea*).

THE POLLEN.—*Formation of Pollen.*—The formation of pollen may be described as follows:—The large cells (*fig.* 374, *cm*), which are developed in the parenchyma of the young anther, and which are destined for its formation, are called *parent* or *mother cells*; these are surrounded in the earlier stages of development by a single stratum of thin-walled cells forming an internal epithelial layer, *cl*, which however becomes subsequently pressed upon and absorbed. As development proceeds the nucleus of each parent cell disappears, and in its place four new nuclei are ultimately formed (*fig.* 402, *a*). Then follows an infolding of the protoplasm, or, according to Mohl, of the primordial utricle, *a*, *b*, *c*, by which the mother-cell is ultimately completely divided into four parts. The four cells thus formed then become each surrounded by a cellulose membrane which is in direct connexion with the cellulose coat of the mother-cell; and thus constitute what are known as the '*special mother-cells.*' Finally, each protoplasmic mass of the special mother-cells separates from the cell-wall and secretes around itself a membrane, so that ultimately we have four perfect cells, *d*, which are the *pollen-cells*, formed in each parent cell.

As development proceeds these pollen-cells increase in size and thus distend the wall of the mother-cell and ultimately cause its absorption; and subsequently, by their continued growth, the walls of the special mother-cells are generally absorbed also, by which the pollen-cells are set free in the cells of the anther. Sometimes the membrane of the special mother-cells is not completely absorbed, in which case the pollen-cells of the mother-cell are more or less connected, and form a compound body consisting of four pollen-cells; or if the membranes of two or more united mother-cells are also incompletely absorbed, we may have a mass consisting of eight pollen-cells, or of some multiple of four, as in many species of *Acacia*. In the Onagraceæ, again, the pollen-cells remain loosely connected by long viscid threads, which appear to be derived from the imperfect

FIG. 402.

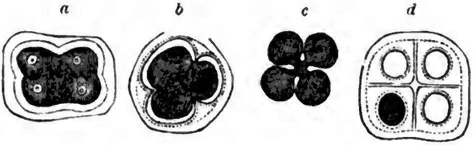


Fig. 402. Formation of the pollen in the Hollyhock (*Althæa rosea*). After Mohl and Henfrey. *a* shows four nuclei in the parent cell, and four septa commencing to be formed. The primordial utricle and cell-contents are contracted by the action of alcohol. *b*. The development of the septa more advanced. *c*. The primordial utricle removed from the parent cell, but not yet completely divided into four parts. *d*. The division of the parent cell into four parts completed, and each part containing one pollen-cell.

solution of the mother-cells; while in the Orchidaceæ the pollen-cells cohere in a remarkable degree, and form pollen-masses which are commonly of a waxy nature, to which the name of *pollinia* has been given (*fig*. 403, *p*). In the Asclepiadaceæ also, somewhat similar masses occur (*fig*. 404, *p*, and *b*); but in the latter, the whole surface of each pollen-mass is invested by a special cellular covering. By a careful examination of these pollinia we find that they are formed of compound masses agglutinated together, and when separated, each of these masses is found to consist of four pollen-cells. In the pollinia of the Orchidaceæ we also find other peculiarities; thus each is prolonged downwards in the form of a stalk called the *caudicle* (*fig*. 403, *c*), which adheres commonly at the period of dehiscence to one or two little glandular masses called *retinacula* (*figs*. 405 *a*, and 403, *r*, *r*), which are placed on the upper surface of a little projection called the *rostellum* situated at the base of the anther.

FIG. 403

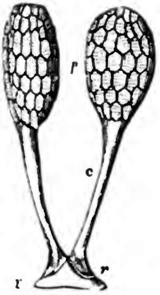


FIG. 404.

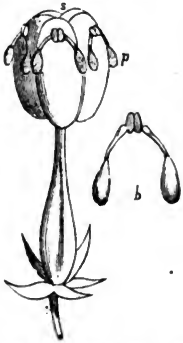


FIG. 405.

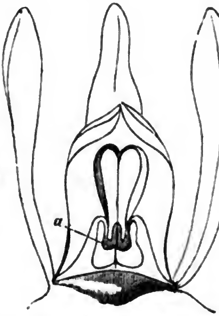


Fig. 403. Pollinia, *p*, of Orchis with their caudicles, *c*, and the retinacula, *r*, *r*, at the base.——*Fig*. 404. Pistil of a species of *Asclepias*, with the pollinia, *p*, adhering to the stigma, *s*. *b*. Pollen-masses separated.——*Fig*. 405. Upper part of the flower of an Orchis, showing the pollinia adhering to the stigma by the retinacula, *a*.

Structure of the Pollen.—We shall treat of this subject under three heads, viz.:—1. Wall; 2. Contents; 3. Form and Size.

1. *Wall or Coats of the Pollen-cell.*—When mature the wall of the pollen-cell generally consists of two membranes; an internal or *intine*, and an external or *extine*. But in rare cases, as in *Zostera*, and some other submersed aquatic plants, there is but one membrane, which is of a similar nature to the intine.

The *intine* is the first formed layer, and appears to be of the same nature and appearance in all pollen-cells. It is usually smooth, very delicate and transparent, and composed of pure cellulose. It is generally applied so as to form a complete lining to the extine, except perhaps in those cases where the latter presents various processes, as in *Œnothera*, when it is probable that the intine does not extend into them in the mature pollen.

FIG. 406.

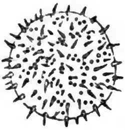


FIG. 407.

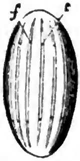


Fig. 406. Pollen of Hollyhock (*Althæa rosea*).——*Fig.* 407. Elliptical pollen of Milkwort (*Polygala*). *e.* Extine. *f.* Slits.

The *extine* is a hard thick resisting layer forming a kind of cuticle over the intine or proper cell-coat; and while the latter usually presents a similar appearance in the pollen of different plants, the extine is liable to great variation; thus it is sometimes smooth, and in other cases marked with little granular processes (*fig.* 54), or spiny protuberances (*fig.* 406), or reticulations. The nature of these markings is always the same for the pollen of any particular species of plant, but varies much in that of different plants. The colour of pollen-cells, which also resides in the extine, is in by far the majority of cases yellow, but various other colours are also occasionally found; thus the pollen-cells are red in species of *Verbascum*, blue in some species of *Epilobium*, black in the Tulip, rarely green, and occasionally of a whitish tint.

Besides the various markings just described as existing on the extine, we find also either *pores* or *slits* (*fig.* 497, *f*), or both pores and slits, and which vary in number and arrangement in different plants. In the greater number of Monocotyledons there is but one slit; while three is a common number in Dicotyledons. Sometimes there are six, rarely four, still more rarely two, and in some cases we find twelve or more slits. The pores, like the slits, also vary as to their number. Thus we commonly find one in Monocotyledons, as in the Grasses; and three in Dicotyledons. Sometimes, again, the pores are very numerous, in which case they are either irregularly distributed, or arranged in a more or less regular manner. The pores, also, may be either simple, or provided with little lid-like processes, as in the Passion-flower and Gourd; these are pushed off by corresponding projections of the intine when the pollen bursts, or when it falls upon the stigma for the purpose of fertilising the ovules.

The pollen of all Angiospermous plants is a simple cell as above described, but in Gymnospermous plants it contains other small cells, which adhere to the inside of its internal membrane close to the point where the external membrane presents a slit. These minute cells are termed daughter-cells.

2. *Contents of Pollen-cells.*—The matter contained within the pollen-cell is called the *fovilla*. This consists of a dense coarsely-granular protoplasm, in which are suspended very small starch granules, and what appear to be oil globules. As the pollen-cell approaches to maturity the fovilla becomes more concentrated, and

contains less fluid matter and more granules. The fovilla is without doubt the essential part of the pollen-cell, but the office it performs will be explained hereafter.

3. *Forms and Sizes of Pollen-cells.*—Pollen-cells are found of various forms. The most common forms appear to be the spherical (*figs.* 54 and 406), and oval (*fig.* 407); but in other cases the pollen-cells are polyhedral, or triangular with the angles rounded and enlarged (trigonal), as in the Evening Primrose and plants generally of the order Onagraceæ, or cubical as in *Basella alba*, or cylindrical as in *Tradescantia virginica*, while in *Zostera* they are thread-like or of the form of a lengthened tube or cylinder, and other forms also occur. It should also be noticed that the form of the pollen is materially influenced according as it is dry or moist. In size, pollen-cells vary from about $\frac{1}{200}$ to $\frac{1}{1000}$ of an inch in diameter; their size, however, like their form, is liable to vary according as they are examined in a dry state or in water.

2. THE DISK.

The term disk is variously applied by botanists; but in this work it is understood to include all bodies of whatever form which are situated on the thalamus between the calyx and gynœcium, or upon or in connexion with either of these organs, but which cannot be properly referred to them, and as it is most commonly placed between the andrœcium and gynœcium, it is best treated of in this place. The disk is developed in a variety of forms; thus in the Rue (*fig.* 409), it forms a fleshy ring surrounding the base of the pistil; in the Tree Pæony (*fig.* 410), it occurs as a dark red cup-shaped expansion covering nearly the whole of the pistil except the stigmas; in the Cherry (*fig.* 391), it forms a sort of waxy lining to the tube of the calyx; and in Umbelliferous plants it exists as a more or less evident swelling on the top of the ovaries adhering to the styles (*fig.* 408, *d*); and has been termed the *stylopodium.* In other cases the disk is reduced to little separate glandular bodies, as in Cruciferous plants (*fig.* 22, *gl*); or to scales, as in the Stonecrop (*fig.* 411); or to various petaloid expansions, as in the Columbine.

FIG. 408.

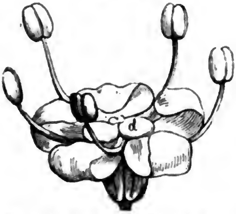


FIG. 409.

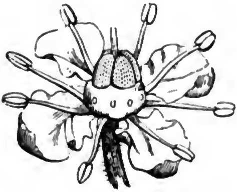


Fig. 408. Flower of the Fennel (*Fœniculum*). The ovary is surmounted by a disk, *d.*——*Fig.* 409. Flower of the Rue (*Ruta graveolens*). The pistil is surrounded by a disk in the form of a fleshy hypogynous ring, on the outside of which the stamens are inserted.

FIG. 410.

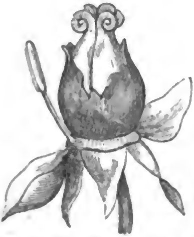


FIG. 411.

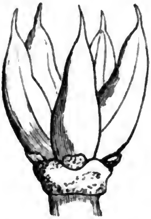


Fig. 410. Pistil of the Tree Pæony (*Pæonia Moutan*) invested by a large cup-shaped disk.——*Fig.* 411. Pistil of Stonecrop (*Sedum*), consisting of five distinct carpels, on the outside of each of which at the base a small scaly body may be noticed. The pistil is compound and apocarpous.

When the disk is situated under the ovary, as in the Rue (*fig.* 409), it is termed *hypogynous*; when it is attached to the calyx, as in the Cherry (*fig.* 391), it is *perigynous*; or when on the summit of the ovary, as in Umbelliferous plants (*fig.* 408, *d*), *epigynous*; these terms being used in the sense already described when treating of the insertion of the stamens under the head of the Andrœcium.

3. THE GYNŒCIUM OR PISTIL.

The gynœcium, or pistil as it is frequently called, is the central or terminal organ of the flower; and it consists of one or more modified leaves called carpels, which are either distinct from each other, as in the Stonecrop (*fig.* 411); or combined into one body, as in the Tobacco (*fig.* 412). When there is but one carpel, as in Leguminous plants (*fig.* 424), the pistil is said to be *simple*; when there is more than one, whether distinct from each other, as in the Stonecrop (*fig.* 411), or combined into one body, as in the Tobacco (*fig.* 412), it is described as *compound*.

FIG. 412.

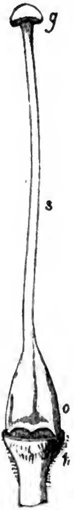


Fig. 412. Compound syncarpous pistil of Tobacco (*Nicotiana Tabacum*). *t.* Thalamus. *o.* Ovary. *s.* Style. *g.* Stigma.

THE CARPEL.—Each carpel, as we have already noticed (page 21), consists, 1st, of a hollow inferior part arising from the thalamus, called the *ovary* (*fig.* 413, *o*), containing in its interior one or more little somewhat roundish or oval bodies called ovules, *ov*, and which are attached to a projection on the walls termed the *placenta*, *p*; and 2nd, of a *stigma* or space of variable size, composed of loose parenchymatous tissue without epidermis; which is either placed directly on the ovary, when it is said to be *sessile*, as in the Barberry (*fig.* 413, *st*); or it is elevated on a stalk prolonged from the ovary, called the *style*, as in the Cherry (*fig*. 418, *s*). The only essential parts of the carpel, therefore, are the ovary and stigma, the style being no more necessary to it than the filament is to the stamen. The terms ovary, style, and stigma are applied in precisely the same sense when speaking of a compound pistil in which the parts are completely united (*fig*. 412), as with the simple carpel. The simple ovary (page 261) has two sutures, one of which corresponds to the union of the margins of the lamina of the carpellary leaf out of which it is formed, and which is turned towards the axis of the plant; and another, which corresponds to the midrib of the lamina, is directed towards the floral envelopes or to the circumference of the flower; the former is called the *ventral suture* (*fig*. 414, *vs*), the latter the *dorsal*, *ds*. (See also page 276.)

FIG. 413.

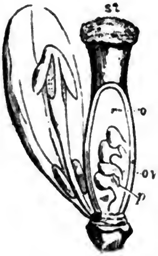


FIG. 414.

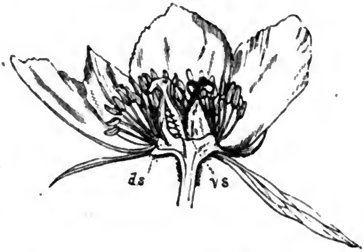


Fig. 413. Vertical section of the ovary of the Barberry (*Berberis vulgaris*), on the outside of which are seen a stamen dehiscing by two valves, and a petal. *o*. Ovary. *ov*. Ovules attached to a projection called the placenta, *p*. *st*. Sessile stigma.——*Fig*. 414. Vertical section of the flower of the Pæony (*Pæonia*). *ds*. Dorsal suture of the ovary. *vs*. Ventral suture.

Nature of the Carpel.—That the carpel is analogous to the leaf is proved in various ways, but we shall here only allude to the proofs of its nature which are afforded by the appearance it sometimes presents in double or cultivated flowers. Thus, in a double flower of the Cherry the carpels do not present a distinct ovary, style, and stigma, as is the normal condition of the solitary carpel in the single flower (*fig.* 418); but they either become flattened into green expansions, each of which resembles the blade of a leaf (*fig.* 415), or into organs intermediate in their nature between carpels and leaves

FIG. 415.

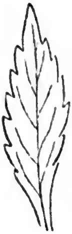


FIG. 416.

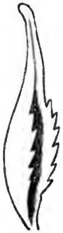


FIG. 417.

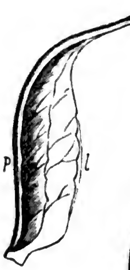


FIG. 418.

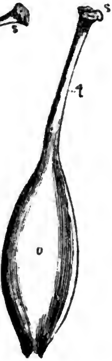
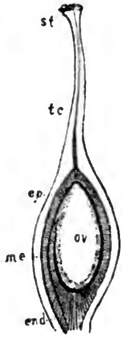


FIG. 419.



Figs. 415–417. Carpellary leaves from the double flowers of the Cherry tree. *l.* Lamina. *p.* Midrib. *s.* Prolonged portion corresponding to the style and stigma of a perfectly formed carpel.——*Fig.* 418. Carpel from the single flower of the Cherry. *o.* Ovary. *t.* Style. *s.* Stigma.——*Fig.* 419. Vertical section of the carpel of the Apricot. *ov.* Ovule, which is enclosed in an ovary. *ep.* Epidermis, forming the external coat of the ovary. *me.* Middle layer. *end.* Inner coat. *tc.* Style with a canal in its centre. *st.* Stigma.

as represented by the figures 416 and 417. Here the lower portion (*fig.* 417, *l*), representing the blade of the leaf, is clearly analogous to the ovary of a complete carpel, and the prolonged portion, *s*, to the style and stigma. The carpel of the single-flowering Cherry being thus convertible into a leaf, affords at once conclusive evidence of its being an analogous structure.

Structure of the Carpel.—The ovary being the homologue (page 176) of the blade of the leaf, it presents, as might have been expected, an analogous structure. Thus it consists of parenchyma, which is often much developed, and through which the vascular bundles composed of spiral and other vessels ramify, and either converge towards the base of the style, or terminate at the upper part of the ovary when the style is absent. The whole is covered externally by a layer of epidermis (*fig.* 419, *ep*). The parenchyma is usually of a more lax nature as we proceed towards the inside of the ovary, where it forms a very delicate lining, *end*, which corresponds to the epidermis of the upper surface of the blade of the leaf. The epidermis on the outside of the ovary corresponds to that of the lower surface of the blade, and like it is frequently furnished with stomata, and sometimes with hairs. The parenchyma, *me*, between the inner lining of the ovary and epidermis corresponds to the general parenchyma of the blade, which is similarly placed. Where the margins of the blade of the carpellary leaf meet and unite at the ventral suture (*fig.* 414, *vs*), a layer of parenchymatous tissue is developed, which forms a more or less projecting line in the cavity of the ovary, called the *placenta* (*fig.* 413, *p*), to which the ovule or ovules are attached. This placenta is essentially double, the two halves being developed from the two contiguous margins of the blade of the carpellary leaf.

The style has been considered by some botanists as a prolongation of the midrib of the blade (*fig.* 417, *p*, *s*), but from the arrangement of its tissue it is to be regarded rather as a prolongation of its apex, the margins of which have been rolled inwards and united. It consists of a cylindrical process of parenchyma, traversed by vascular tissue, which is so arranged as to form a sort of sheath at its circumference, and is a continuation of that of the ovary; it proceeds upwards without branching towards the apex of the style, but always terminates below that point. The style is invested by epidermis continuous with that of the ovary, and furnished occasionally, like it, with stomata and hairs.

FIG. 420.

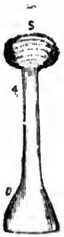


FIG. 421.

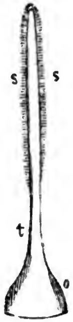


FIG. 422.

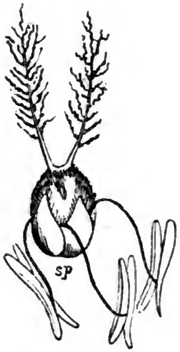


Fig. 420. A portion of the pistil of ***Daphne Laureola.*** ***o.*** Summit of the ovary. ***t.*** Style terminated by a papillose stigma, ***s.***——*Fig.* 421. A portion of the pistil of ***Plantago saxatilis.*** ***o.*** Summit of the ovary. ***t.*** Style. ***s, s.*** Bilateral stigma.——*Fig.* 422. Pistil of Wheat surrounded by three stamens, and two squamulæ, ***sp.*** Two feathery styles or stigmas arise from the top of the ovary.

The style is rarely traversed by a very narrow canal (*fig.* 419, *tc*) which communicates below with the cavity of the ovary, and above with the stigma. But commonly the centre of the style is filled with a tissue formed of very loosely aggregated cells; and when the carpel is fully matured, that is, at the period when it is adapted for receiving the influence of the pollen, these cells, as well as those of the stigma, secrete a peculiar viscid fluid which is called the stigmatic fluid, so that at the period of fertilisation, the centre of the style is filled with very loose humid tissue; this has received the name of *conducting tissue*, because from its loose nature and nourishing properties it serves to conduct (as it were) the pollen-tubes down the styles to the placenta and ovules, as will be explained hereafter.

The Stigma.—The tissue of the stigma is analogous to that found in the interior of the style, and just described under the name of conducting tissue; in fact, it seems to be nothing more than an expansion of this tissue externally. It may be either on one side of the style (*fig.* 423), or at its apex (*fig.* 420), or on both sides (*fig.* 421); and its tissue is usually elongated into papillæ (*fig.* 420, *s*), or hair-like or feathery processes (*fig.* 422). It is never covered by epidermis. By means of the corresponding conducting tissue of the style it is in direct continuity with the placenta. At the period of fertilisation, as just noticed, it becomes moistened by a viscid fluid which renders the surface more or less sticky, and thus admirably adapted to retain the pollen, which is thrown upon it in various ways in the process of pollination.

FIG. 423.

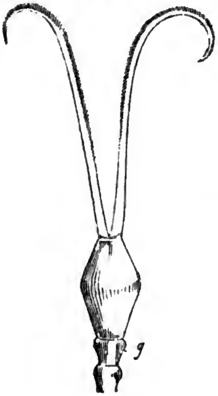


FIG. 424.

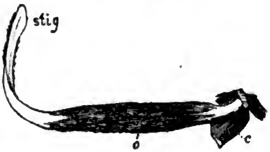


Fig. 423. Pistil of *Dianthus Caryophyllus* on a stalk, *g*, called the gynophore, below which is the peduncle. On the top of the ovary are two styles, the face of each of which is traversed by a continuous stigmatic surface.——*Fig.* 424. Pistil of a species of *Lathyrus*. *o*. Ovary. *c*. Remains of the persistent calyx. On the top of the ovary is the style, and stigma, *stig*.

THE GYNŒCIUM.—Having now described the parts, nature, and structure of the carpel, we proceed to examine generally the gynœcium or pistil, which is made up of one or more of such carpels.

When the gynœcium is formed of but one carpel, as in Leguminous plants (*fig.* 424), it is called *simple*, and the terms gynœcium and carpel are synonymous; when there is more than one carpel, the gynœcium is called *compound* (*fig.* 411). In a compound pistil, again, the carpels may be either separate from each other, as in the Stonecrop (*fig.* 411); or united into one body, as in the Tobacco (*fig.* 412): in the former case the pistil is said to be *apocarpous*, in the latter *syncarpous*.

When the pistil is apocarpous, the number of carpels of which it is composed is indicated by a Greek numeral prefixed to the termination *gynous*, which means female, in reference to the function it performs in the process of fertilisation; and the flower receives corresponding names accordingly. In a syncarpous pistil, the number of the styles, or of the stigmas if the styles are absent, is also defined in a similar way. Thus, a flower with one carpel, style, or stigma is *monogynous*, with two *digynous*, with three *trigynous*, and so on.

1. *Apocarpous Pistil.*—An apocarpous pistil may consist of two or more carpels, and they are variously arranged accordingly. Thus, when there are but two, they are always placed opposite to each other; when there are more than two, and the number coincides with the sepals or petals, they are opposite or alternate with them; it is rare, however, to find the carpels corresponding in number to the sepals or petals, they are generally fewer, or more numerous. The carpels may be either arranged in one whorl, as in the Stonecrop (*fig.* 411); or in several whorls alternating with each other, and then either at about the same level, or, as is more generally the case, at different heights upon the thalamus in a more or less spiral manner; and under these circumstances the thalamus becomes variously modified, as will be explained hereafter when it is described.

2. *Syncarpous Pistil.* We have already seen, in

speaking of the floral envelopes and andrœcium, that the different parts of which these whorls are respectively composed may be distinct from each other, or more or less united. From the position of the carpels with respect to one another, and from their nature, they are more frequently united than any other parts of the flower. This union may take place either partially, or entirely, and it may commence at the summit, or at the base of the carpels. Thus in the former case, as in *Xanthoxylon fraxineum* (*fig.* 425), the carpels are united by their stigmas only; in *Dictamnus Fraxinella* (*fig.* 433), the upper parts of their styles are alone united; while in the order Labiatæ, and most Boraginaceæ (*fig.* 426, *d*), the whole of the styles are united, the ovaries being distinct as in the former cases.

FIG. 425.

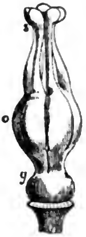


FIG. 426.

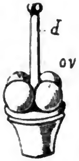


FIG. 427.

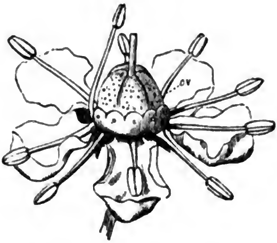


Fig. 425. Pistil of ***Xanthoxylon fraxineum*** supported on a gynophore, *g*. The ovaries, *o*, and styles are distinct, but the stigmas, *s*, are united.——*Fig.* 426. Pistil of ***Myosotis***, a Boraginaceous Plant. *or*. Distinct ovaries. *d*. Styles united.——*Fig.* 427. Flower of Rue (***Ruta graveolens***), showing the ovaries, *ov*, united at their bases.

It is, however, far more common to find the carpels united by their ovaries, and this union may also take place to various extents. Thus, in the Rue (*fig.* 427, *ov*), the union only takes place at the base of the ovaries; in *Dianthus* (*fig.* 423) the ovaries are completely united, the styles being distinct; while in the Tobacco (*fig.* 412), the ovaries, styles, and stigmas are all united. When two or more ovaries are thus completely united so as to form one body, the organ resulting from their union is called a *compound ovary.*

Compound Ovary.—The compound ovary formed as just stated may either have as many cavities separated by partitions as there are component ovaries; or it may only have one cavity. These differences have an important influence upon the attachment of the ovules, as will be afterwards seen when speaking of placentation; hence it is necessary to explain at once the causes which lead to these differences Thus if we have three carpels placed side by side (*fig.* 428, *a*), each of these possesses a single cavity corresponding to its ovary, so that if we make a transverse section of the whole, *b*, we necessarily have three cavities, each of which is separated from those adjoining by two walls, one being formed by the side of its own ovary, and the other by that of the one next to it. But if these three carpels, instead of being distinct, are united by their ovaries (*fig.* 429, *a*), so as to form a compound ovary,

FIG. 428.

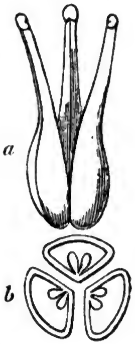


FIG. 429.

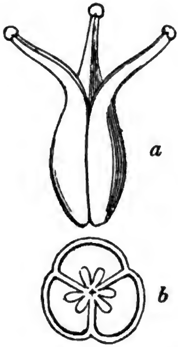


Fig. 428. *a.* Diagram of three carpels placed side by side but not united. *b.* A transverse section of the ovaries of the same.—— *Fig.* 429. *a.* Diagram of three carpels united by their ovaries, the styles and stigmas being free. *b.* A transverse section of the ovaries of the same.

the latter must necessarily also have as many cavities, *b*, as there are component carpels, and each cavity must be separated from those adjoining by a wall which is called a *dissepiment* or *partition*, and which is necessarily formed of the united sides of the two adjoining ovaries.

The cavities of the compound ovary are called *cells* or *loculi*, and such an ovary as that just described would be therefore termed *three-celled* or *trilocular*, as it is formed of three united ovaries; or if formed of the united ovaries of two, four, five, or many carpels, it would be described respectively as *two-celled*, *four-celled*, *five-celled*, or *many-celled*. As all dissepiments are *spurious* or *false* which are not formed by the united walls of adjoining ovaries, it must necessarily follow that a single carpel can have no true dissepiment, and is hence, under ordinary and normal circumstances, *one-celled*.

From the preceding observations it must also follow that when ovaries which are placed side by side cohere, and form a compound ovary, the dissepiments must be vertical, and equal in numbers to the ovaries out of which that ovary is formed. When a compound ovary is composed, however, of several whorls of ovaries placed in succession one over the other, as in the Pomegranate, horizontal true dissepiments may be formed by the ovaries of one whorl uniting by their bases to the apices of those placed below them.

We have just observed that all dissepiments are said to be spurious except those which are caused by the union of the walls of contiguous ovaries, and it occasionally happens that such spurious dissepiments are formed in the course of growth, by which the ovary acquires an irregular character. These false dissepiments commonly arise from projections of the placentas inwards; or by corresponding growths from some other inner part of the walls of the ovaries. Some of these are horizontal, and are called *phragmata*, as in the *Cassia Fistula* (*fig.* 487), where the ovary, after fertilisation, is divided by a number of transverse dissepiments, which are projections from its walls. Others are vertical, as in Cruciferous plants, where the dissepiment, called a *replum* (*fig.* 503, *cl*), is formed from the placentas.

When a *compound ovary presents but one cavity, instead of two or more, as in that just alluded to,* such an ovary is formed either by the union of the contiguous margins of the flattened open ovaries of the carpels of which it is composed, as in the Mignonette (*fig.* 430); or by the union of carpels, the ovaries of which are only partially folded inwards, so that all their cavities communicate in the centre, as in the Orchis (*fig.* 431), and Poppy (*fig.* 432).

FIG. 430.

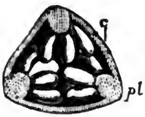


FIG. 431.

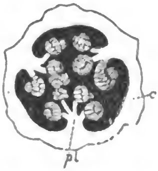


FIG. 432.

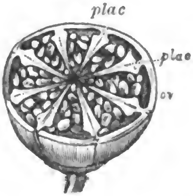


Fig. 430. Transverse section of the one-celled ovary of Mignonette (*Reseda*). *c.* The lower flattened portion or ovary of one of the three carpels of which it is formed. *pl.* One of the three parietal placentas.——*Fig.* 431. Transverse section of the one-celled ovary of an Orchis. *c.* The lower portion or ovary of one of the three carpels of which it is formed, slightly infolded. *pl.* One of the three placentas.——*Fig.* 432. Transverse section of the ovary of a species of Poppy. *ov.* Ovules. *plac, plac.* Placentas, which in the young ovary nearly meet in the centre, and thus the ovary becomes almost many-celled, but as the ovary progresses in development it becomes distinctly one-celled.

Having now described the parts, nature, and structure of the carpel, and of the gynœcium generally, we proceed in the next place to allude separately to the constituent parts of the carpel, both in a free and combined state, namely, the ovary, style, and stigma.

1. THE OVARY.—The ovary, as already mentioned (page 258), is called *compound* when it is composed of two or more ovaries combined together; or, on the

contrary, it is *simple* when it constitutes the lower part of a simple pistil (*fig.* 424, *o*), or of one of the carpels of an apocarpous pistil (*fig.* 411). It should be noticed, therefore, that the terms simple pistil and simple ovary are not in all cases synonymous terms; thus, a pistil is only said to be simple (*fig.* 424), when it is formed of but one carpel, the terms pistil and carpel being then mutually convertible; but an ovary is simple, as just noticed, whether it forms part of a simple pistil, as in Leguminous plants (*fig.* 424), or of one of the carpels of an apocarpous pistil, as in the Stonecrop (*fig.* 411).

FIG. 433.

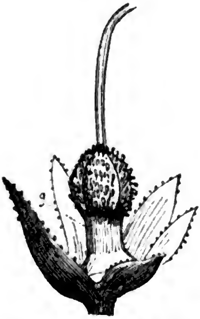


FIG. 434.

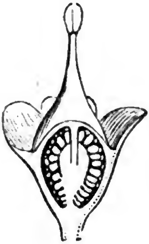


Fig. 433. Pistil of ***Dictamnus Fraxinella***. The ovary is supported on a gynophore, *g*, and is superior.——*Fig.* 434. Vertical section of the flower of a Saxifrage, showing the ovary partially adherent to the calyx.

An ovary is also said to be *monomerous* when it is formed of only one carpel; or *dimerous*, *trimerous*, *tetramerous*, or *polymerous*, when it is formed by the coherence of two, three, four, or many carpels.

Generally speaking, the ovary is *sessile* upon the thalamus, but in rare cases it is more or less elevated above the outer whorls, when it is said to be *stalked* or *stipitate*, as in the *Dictamnus* (*fig.* 433, *g*), and the stalk has received the name of *gynophore*.

The ovary, whether simple or compound, may be either adherent to the calyx or free from it. When adherent, as in the Myrtle (*fig.* 331), it is *inferior* or *adherent*, and the calyx *superior*; in the latter case, as in *Dictamnus* (*fig.* 433), it is *superior* or *free*, and the calyx *inferior*. In some flowers the ovary is but partially adherent to the calyx, as in the species of Saxifrage (*fig.* 434), in which case it is sometimes termed *half-adherent* or *half-inferior*; and the calyx is then said to be *half-superior*. These latter terms are however but little used.

The ovary varies much much in form, and in the character of its surface, but as in these cases the same terms are used as in describing similar conditions of the leaves, and the other organs of the plant, they require no further notice.

FIG. 435.

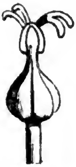


FIG. 436.

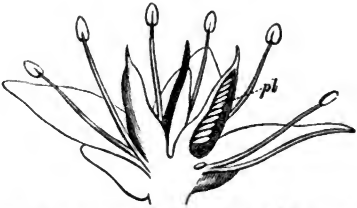


Fig. 435. Pistillate flower of a species of *Euphorbia*, with three forked styles.——*Fig.* 436. Vertical section of the flower of the Stonecrop. *pl.* Placenta of one of the ovaries arising from the ventral suture.

When the ovary is compound, the number of carpels of which it is composed may be ascertained in one or more of the following ways. Thus, when the styles (*fig.* 332), or stigmas (*fig.* 375), remain distinct, the number of these generally corresponds to the number of carpels. It does, however, occasionally happen, as in *Euphorbia* (*fig.* 435), that the styles are themselves divided, in which case they would of course indicate a greater number of carpels than are actually present; we must then resort to other modes of ascertaining this point, such, for instance, as the furrows, or lobes on the external surface of the ovary, which commonly correspond to the points of union of its component ovaries; or the number of partitions or cells which it contains, as these commonly correspond in number to the carpels of which that ovary is composed; or in other cases to the manner in which the ovules are attached, which we must now proceed to consider.

Placentation.—The term *placenta* is commonly applied to the more or less marked projection found in the cavity of the ovary (*figs.* 413, *p*, and 436, *pl*), to which the ovule or ovules are attached. The term *placentation* is used to indicate the manner in which the placentas are distributed.

FIG. 437.

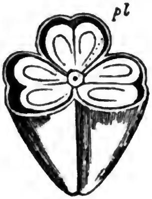


FIG. 438.

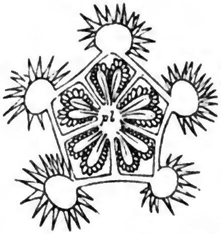


Fig. 437. Transverse section of the compound ovary of the Lily. The ovary is three-celled or trilocular. The placentas, *pl*, are axile or central.——*Fig* 438. Transverse section of the ovary of a species of *Campanula*. The ovary is five-celled or quinquelocular, and the placentation, *pl*, axile or central.

1. *Kinds of Placentation.*—In the simple ovary the placenta is always situated at the ventral suture, or that point which corresponds to the union of the two margins of the lamina of the carpellary leaf (*fig.* 436) out of which it is formed; such a placenta is therefore usually termed *marginal*.

In compound ovaries we have three regular kinds of placentation; namely, *axile* or *central*, *parietal*, and *free central*. The *axile* occurs in all compound many-celled ovaries, because in these each of the ovaries of the component carpels is placed in a similar position to that of the simple ovary (*figs.* 428, *b*, and 429, *b*), and hence the placentas situated at their ventral sutures will be arranged in the centre or axis, as in the Lily (*fig.* 437), and *Campanula* (*fig.* 438, *pl*).

In a compound one-celled ovary there are two forms of placentation, namely, the *parietal*, and the *free-central*. The placentation is termed *parietal*, when the ovules are attached to placentas either placed directly on the inner wall of the ovary, as in the Mignonette (*fig.* 430, *pl*); or upon incomplete dissepiments formed as already noticed, by the partially infolded ovaries, as in the species of *Orchis* (*fig.* 431, *pl*) and Poppy (*fig.* 432, *plac*). When the placentas are not attached to the inner wall of the ovary, but are situated in the centre of the cavity and perfectly unconnected with the wall, they form what is called a *free central placenta*, as in the Caryophyllaceæ (*fig.* 439), and the Primulaceæ (*fig.* 440, *pl*).

FIG 439.

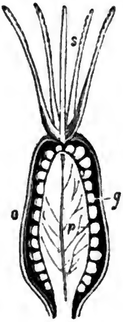


FIG. 440.

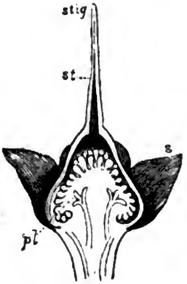


Fig. 439. Vertical section of *Cerastium hirsutum* (*Caryophyllaceæ*). *o.* Ovary. *p.* Free central placenta. *g.* Ovules. *s.* Styles and stigmas.——*Fig.* 440. Vertical section of the pistil of Cyclamen (*Primulaceæ*). *s.* Sepals. *pl.* Free central placenta. *st.* Style. *stig.* Stigma.

Besides the above regular kinds of placentation, it rarely happens that the ovules are placed more or less irregularly in the cavity of the ovary. Thus, in the Flowering Rush (*Butomus*) they cover the whole inner surface of the ovary except the midrib; in this case the placentation is sometimes described as *superficial*. Other irregularities also occur.

2. *Origin of the Placenta.*—It is generally believed that the placenta is, in most cases at least, a cellular growth developed from the confluent margins of the carpels, or, more strictly speaking, from the confluent margins of the laminæ of the carpellary leaves, and either, as is generally the case, extending along the whole line of union of the carpel (*fig.* 436, *pl*), or, in some cases, confined to its base or apex. Each placenta is therefore to be considered as composed of two halves, one half being formed by each margin of the carpel. Thus in simple ovaries the placenta is developed by a single carpel; in compound two or more celled ovaries the placentas are in like manner formed from the contiguous margins of each individual carpel of which it is composed; while in compound one-celled ovaries presenting parietal placentation, each placenta is formed from the contiguous margins of two carpels and is hence produced by two adjoining carpels.

But in reference to the origin of the free central placenta two different views are entertained. Thus it was formerly supposed that this also was a development from the margins of the carpels. It was thought that the carpels of which the compound ovary was formed originally met in the centre and developed placentas from their margins in the same manner as in ordinary axile placentation, but that subsequently the walls of the ovary grew more rapidly than the dissepiments, so that the connexion between them was soon destroyed; and that from this cause, and also from the great subsequent development of the placenta, the septa ultimately became almost or quite broken up, so that the placenta was left free in the cavity of the ovary. This theory is strengthened by the fact, that in several of the

Caryophyllaceæ we often find dissepiments in the young ovary; and even traces of these at the lower part of the mature ovary; hence it may be concluded that these are the remains of dissepiments which have become ruptured on account of the unequal development of the parts of the ovary. In the Primrose, however, and many other plants, which have a free central placenta, no traces of dissepiments can be found at any period of the growth of the ovary. The formation of such a free central placenta cannot therefore be well explained upon the marginal theory, as the carpels have never had any connexion with it except at their bases. Hence this kind of placentation has been supposed by many botanists not to be formed from the carpels at all, but to be a prolongation of the axis, which bears ovules, instead of buds as is the case with branches. It seems most probable therefore that the origin of the free central placenta is sometimes from the axis, as in the Primrose; and that at others, as in the Caryophyllaceæ, it is originally axile, and becomes ultimately free by the obliteration of the dissepiments.

2. The Style.—The style usually arises from the geometrical summit of the ovary of which it is a continuation in an upward direction, as in the Tobacco (*fig.* 412): it is then termed *apicilar* or *apical.* In other cases the apex of the ovary becomes inflected towards the side or base, from the carpel or carpels of which it is formed being folded like ordinary leaves in reclinate vernation; the style then becomes *lateral* as in the Strawberry (*fig.* 441), or *basilar* as in *Alchemilla* (*fig.* 442).

The style is generally directly continuous with the ovary, in which case it is more or less *persistent*, and then forms a more or less evident part of the fruit (page 271); at other times, however, the style always falls off after the process of fertilisation is completed, in which case it is said to be *deciduous*, and has no connexion with the fruit.

When the style is basilar or lateral, and the ovary to which it is attached more or less imbedded in the thalamus, it frequently appears to spring from the latter part; such an arrangement is called a *gynobase*, and the ovary is said to be *gynobasic*. Thus in the Labiatæ and Boraginaceæ (*fig.* 426), the four ovaries are free, but the styles become connected and form a central column, which appears therefore to be a prolongation of the thalamus.

When two or more styles are united into one body, this is termed a *compound style*. This adhesion may take place either entirely, as in the Tobacco (*fig.* 412), when the style is termed *simple*, or, more properly, *entire*; or the union is more or less incomplete as we proceed towards its apex, and corresponding terms are used accordingly. These terms are similar to those previously mentioned in describing the degrees of division in the other parts of the plant: thus the style is said to be *cleft*, *partite*, &c., according to the depth to which it is divided, and further characterised as *bifid*, *trifid*, *bipartite*, *tripartite*, &c., according to the number of its divisions.

FIG. 441. FIG. 442.

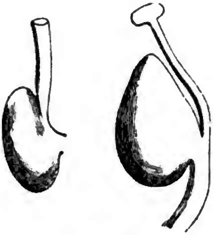


Fig. 441. One of the carpels of the Strawberry with a lateral style.—— *Fig.* 442. Carpel of *Alchemilla* with a basilar style. The stigma is capitate.

The style is also subject to variations of form as *cylindrical*, *filiform*, &c.; or when flattened and coloured like a petal, as in the Iris (*fig.* 443, *sty*), it is said to be *petaloid*. Again, the surface of the style may be either smooth, or covered in various ways with glands or hairs. These hairs when situated on the style frequently serve the purpose of collecting the pollen as it is discharged from the anther, and are hence termed *collecting hairs* (*fig.* 445, *pc*). In certain natural orders, as the Goodeniaceæ and the Lobeliaceæ, the hairs form a little ring below the stigma (*fig.* 444, *i*), to which the term of *indusium* has been given.

3. The Stigma.—The stigma has been already described (page 255), as being connected with the placenta by means of the conducting tissue of the style; hence it may be considered as a portion of the placenta prolonged upwards, but differing from it in not bearing ovules.

The stigmas of a syncarpous pistil are generally opposite to the cells of the ovary, and alternate with the dissepiments, but it sometimes happens, as in the Poppy (*fig.* 27), that half the stigma of one carpel unites with a similar half of that of the adjoining carpel, and thus it becomes alternate with the cells, and opposite to the dissepiments, which are here, however, imperfect (*fig.* 432).

Fig. 443.

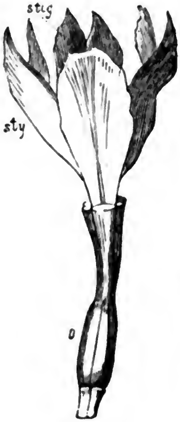


Fig. 444.

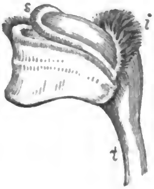


Fig. 445.

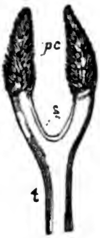


Fig. 443. Pistil of a species of *Iris*. *o*. Ovary. *sty*. Petaloid styles. *stig*. Stigmas.——*Fig.* 444. Upper part of the style and stigma of *Leschenaultia formosa*. *t*. Style. *s*. Stigma. *i*. Indusium ——*Fig.* 445. Upper part of the style, *t*, of a Composite Plant dividing into two branches, which are covered above by collecting hairs, *pc* *s*. True stigma.

The term stigma is only properly applied to that portion of the style which is destitute of epidermis, and which secretes the stigmatic fluid; but it is often improperly given to mere divisions of the style. Thus in the species of *Iris* (*fig.* 443), the three petaloid portions of the style are in descriptive botany commonly termed petaloid stigmas; whereas the stigma is properly confined to a little transverse space, *stig*, near the apex of each division.

In a syncarpous pistil the stigmas may be either united together as in the Tobacco (*fig.* 412), or distinct as in the *Campanula* (*fig.* 364); in the latter case, instead of looking upon these separate parts as so many distinct stigmas, it is usual to describe them as if they were portions of but one; thus we speak of the stigma as *bifid*, *trifid*, &c., or as *bilobate*, *trilobate*, &c., according to the number and character of its divisions. Thus the term *lobe* is usually applied when the divisions are thick, as in the Lily (*fig.* 446) and Melon (*fig.* 447); or when these are flattened and somewhat strap-shaped, as in the Compositæ (*fig.* 448), the stigma is *fissured* or *cleft*; or when flattened into plates or bands they are termed *lamellæ*, as in the *Bignonia* (*fig.*

FIG. 446.

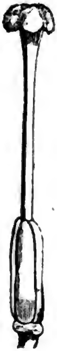


FIG. 447.

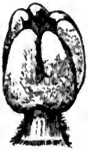


FIG. 448.

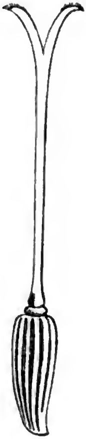


Fig. 446. Pistil of Lily, with one style and a trilobate stigma.——*Fig.* 447. Lobed stigma of Melon.——*Fig.* 448. Pistil of a species of *Chrysanthemum*, with one style and a bifid stigma. the divisions with hairs at their extremities.

449). The number of these divisions in the majority of instances corresponds to the number of carpels of which the pistil is composed; and if the compound ovary of the latter is two or more celled, the number of cells will generally correspond also to the divisions of the stigma.

FIG. 449.

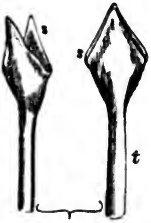


FIG. 450.

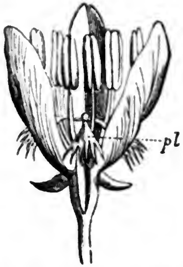


Fig. 449. Stigma, *s*, attached to style, *t*, of *Bignonia arborea.* In the left-hand figure the *lamellæ* are separate, in the other applied closely to each other.——*Fig.* 450. Flower of a species of *Rumex*, showing fringed stigmas, *pl.*

FIG. 451.

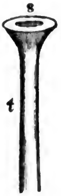


FIG. 452.

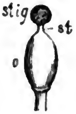


FIG. 453.

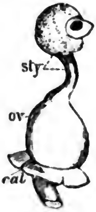


Fig. 451. *s.* Peltate or shield-shaped stigma surmounting the style, *t*, of a species of *Arbutus.*——*Fig.* 452. Pistil of *Daphne.* *o.* Ovary. *st.* Style. *stig.* Stigma.——*Fig.* 453. Pistil of Pansy (*Viola tricolor*). *cal.* Remains of calyx. *ov.* Ovary. *sty.* Style, surmounted by an irregular hooded stigma.

The lobes assume different appearances: thus, they may be smooth, or thick and fleshy, as in the Melon (*fig.* 447), or feathery, as in many Grasses (*fig.* 422), or fringed or laciniate, as in the *Rumex* (*fig.* 450, *pl*).

When the stigmas are united, the number of parts in the compound stigma is usually indicated by radiating furrows or grooves. When the stigmas unite and form a compound body upon the top of the style, which is larger than it, this compound stigma or head is said to be *capitate*; and this head may be either globular, as in *Daphne* (*fig*. 452, *stig*); or hemispherical, as in the Primrose; or polyhedral, or club-shaped, or peltate or shield-shaped, as in the *Arbutus* (*fig*. 451, *s*). In the Violet (*fig*. 453), the stigma presents an irregular hooded appearance.

4. THE THALAMUS.

The extremity of the peduncle or pedicel, or any part of the axis upon which the parts of a solitary flower are arranged, has been variously distinguished by botanists as the *thalamus*, *receptacle*, and *torus*. The use of these names indifferently has led to much confusion; and the uncertainty is still further increased in consequence of the terms receptacle and torus being also sometimes applied in a different sense. Thus, that of receptacle is employed in a special manner, as already mentioned (page 183); while the term torus is used by some botanists as synonymous with disk. To prevent confusion, therefore, it would be far better to limit the terms receptacle and torus to their special applications; and use the term thalamus only as defined above, and as it is employed in this work.

In the majority of plants the thalamus is a little flattened surface or point, but in other plants it becomes much enlarged, and then assumes a variety of appearances, and thus modifies to a considerable extent the form of the flower. Thus in the plants of the order Magnoliaceæ generally, the thalamus is cylindrical (*fig*. 454, *a*); in the Raspberry (*fig*. 456, *l*) and species of *Ranunculus* it is conical; in the Strawberry (*fig*. 455), hemispherical; in *Nelumbium* (*fig*. 457, *thal*), it is a large tabular expansion, in which there are a number of cavities containing the separate carpels. In the Rose it forms a concavity upon which the carpels are placed (*fig.* 324, *r*, *r*).

FIG. 454.

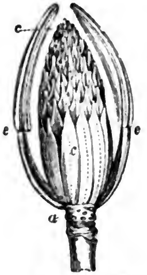


FIG. 455.

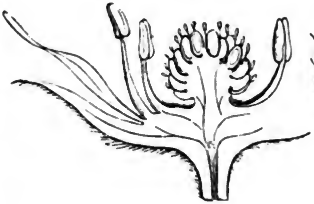


FIG. 456.

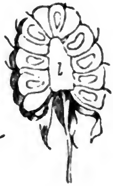


Fig. 454. Central part of the flower of the Tulip tree (*Liriodendron tulipifera*). The thalamus, *a*, is more or less cylindrical. *c*, *c*. Carpels. *e*, *e*. Stamens.——*Fig.* 455. Section of the flower of the Strawberry. The thalamus is nearly hemispherical, and bears a number of separate carpels on its upper portion.——*Fig.* 456. Section of the fruit of the Raspberry, showing the conical thalamus, *l*.

In the Primulaceæ, Santalaceæ, and in all cases where the placenta is free from the wall of the ovary from its earliest appearance, the thalamus becomes prolonged into the cavity of the ovary and forms the placenta (*fig.* 440). At other times the thalamus becomes prolonged beyond the ovary, as in the Geraniaceæ and Umbelliferæ; this prolongation is termed a *carpophore.* In the species of *Geranium* (*fig.* 458, *c*), this carpophore forms a long beak-like process to which the carpels, *car*, are attached, and from which they separate when the fruit is ripe.

FIG. 457.

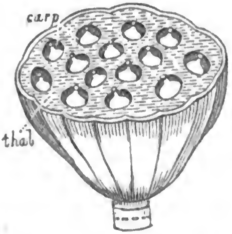


Fig. 457. *thal.* Thalamus of *Nelumbium*. *carp.* Carpels.

In some plants the thalamus becomes prolonged beyond the calyx, and forms a stalk to the ovary, to which the term *gynophore* has been applied; and upon this stalk the stamens are also commonly placed, and in some cases the petals as well. Examples of this may be seen in some of the Capparidaceæ (*fig*. 459, *thal*), in the Pink (*fig*. 423, *g*), *Dictamnus* (*fig*. 433, *g*), and *Xanthoxylon* (*fig*. 425, *g*).

FIG. 458.

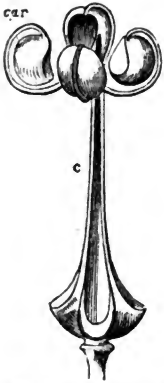


FIG. 459.

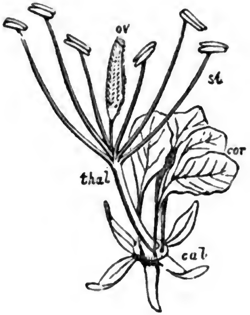


Fig. 458. The carpophore, *c*, of a species of *Geranium*, with the rolled-back carpels, *car*.——*Fig*. 459. Flower of a species of *Gynandropsis*, belonging to the Capparidaceæ. *cal*. Calyx. *cor*. Corolla. *thal*. Prolonged thalamus or gynophore, supporting the stamens, *st*, and ovary, *ov*.

Section 5. THE FRUIT.

NATURE AND GENERAL CHARACTERS OF THE FRUIT.—After the process of fertilisation has been effected, important changes take place in the gynœcium and surrounding organs of the flower, the result of which is the formation of the fruit. The fruit however consists essentially of the ripened ovary or ovaries containing the fertilised ovule or ovules, which are then termed seeds. Even the styles and stigmas mostly disappear, but the remains of the style frequently exist in the form of a little point on the fruit, which is then commonly described as *apicilar*, and in this way small fruits, such as those of Labiate plants, and of the Boraginaceæ, Umbelliferæ, and others, may be known from seeds.

Although the fruit is thus described as consisting of the fertilised gynœcium, other parts of the flower are also frequently present, and enter into its composition. Thus, in those cases where the calyx is adherent to the ovary, as in the Quince (*fig.* 340), Melon, and Gooseberry, it necessarily forms a part of the fruit; in the Rose the concave thalamus (*fig.* 324, *r*, *r*), which bears the carpels on its inner surface, and the adherent calyx-tube, *ct*, become a portion of the fruit; in the Strawberry (*fig.* 455 and 495), the fruit consists of the succulent hemispheric thalamus, bearing the carpels on its convex surface; in the Acorn (*fig.* 282), it consists of pistil, calyx, and bracts, combined together; while in the Pineapple (*fig.* 278), it is composed of the ovaries, floral envelopes, and bracts of several flowers; in the Fig also (*fig.* 288) we have a fruit which is formed of a number of separate flowers enclosed in a fleshy receptacle. These examples will show, that although the fruit consists essentially of the mature ovary or ovaries, enclosing the fertilised ovules or seeds, yet the term is also applied to whatever is combined with the gynœcium, so as to form a covering to the seed or seeds. All fruits, however, which are not formed entirely out of the fertilised gynœcium, but which consist in part of other portions of the flower or peduncle, are frequently called *spurious fruits*.

As the fruit is formed essentially of the ovary, the modifications which it presents are described by similar terms. Thus we may have *simple* and *compound* fruits, as also *apocarpous* and *syncarpous* ones. Simple fruits, like simple ovaries, are normally *one-celled* or *unilo-*

cular; while a compound fruit may have one or more cells or loculi, according as the dissepiments are absent or present, and the number of cells is indicated by similar terms to those used when speaking of the compound ovary (page 259).

The fruit, like the ovary, also necessarily possesses a placenta, to which the seeds are attached; and the same terms are used in describing the different kinds of placentation, as with those of the ovary; these kinds are usually more evident in the fruit.

The fruit, again, is described as *superior* or *inferior*, in the same sense as these terms are used in speaking of the ovary. Thus a fruit is inferior, when it is formed from an inferior ovary, in which case the calyx necessarily enters into its composition, as in the Melon, Quince, and Gooseberry; or it is superior, as in the Poppy and Orange, when the ovary is superior, and the calyx non-adherent.

COMPOSITION OF THE FRUIT.—The fruit when perfectly formed consists of two parts; namely, the *shell* or *pericarp*, and the *seed* or *seeds* contained within it. The seeds will be fully noticed after we have become acquainted with the structure of the ovules, but we must now proceed to describe the pericarp.

In the majority of fruits the pericarp consists simply of the walls of the ovary in a modified state; but, when the calyx is adherent, it necessarily presents a more complicated structure. The pericarp exhibits three layers or regions (*fig.* 490): an external, called the *epicarp*, *ep*; a middle, the *mesocarp*, *mt*; and an inner, the *endocarp*, *en*. The middle layer, being frequently of a fleshy or succulent nature, is also then termed the *sarcocarp*; while the inner layer, from its hardness in some fruits, is likewise called the *stone* or *putamen*. In many fruits these layers are not clearly distinguishable, but in others readily so. Thus in the Peach, Cherry, and Plum, the separable skin is the epicarp; the pulpy part, which is eaten, the mesocarp or sarcocarp; and the stone enclosing the seed, the endocarp or putamen. In the Apple and Pear, the skin is the epicarp; the fleshy part, which is eaten, the mesocarp or sarcocarp; and the core containing the seeds, the endocarp. A similar disposition of parts occurs in the Medlar, except that here the core becomes of a stony nature. In the Walnut, the woody shell enveloping the seed, which is commonly termed the nut, is the endocarp; and the green covering of this, called the husk, consists of the mesocarp and epicarp combined. In the Orange, the outer separable rind is also composed of the combined mesocarp and epicarp; and the thin membranous partitions which divide the pulp into separate portions form the endocarp; the edible pulp itself is a development of succulent parenchyma from the inner lining of the ovary, or probably from the placentas only. These few examples of fruits, together with those previously alluded to, will show in a striking manner the very varying nature and origin of the parts which are commonly eaten.

Sutures.—In describing the structure of the carpel, we found that the ovary presented two sutures (page 251); one of which, called the ventral suture, corresponded to the union of the margins of the lamina of the carpellary leaf, and was consequently turned towards the axis or centre of the flower; and the other, termed the dorsal suture, corresponded to the midrib of the lamina of the carpellary leaf, and was directed towards its circumference. The simple fruit being formed, in most cases, essentially of the fertilised ovary, also presents two sutures, which are distinguished by similar names. These, like those of the ovary, may be frequently distinguished externally, either by a more or less projecting line, or by a slight furrow; thus in the Peach (*fig.* 488), the ventral suture is very evident, although the dorsal suture has become nearly effaced; while in the Pea, and other fruits of the Leguminosæ, both dorsal and ventral sutures are clearly visible externally.

In a compound ovary with two or more cells, in which the placentation is axile, it must be evident, of course, that the dorsal sutures can alone be observed externally, as the ventral sutures of the component ovaries are turned towards, and meet in, the axis of the flower, and are hence removed from view; it follows also that the number of dorsal sutures will necessarily correspond to the number of component ovaries of which such an ovary is formed. In a fruit presenting similar characters, we find of course a similar disposition of the sutures. When an ovary, on the contrary, is formed of the blades of two or more carpellary leaves, the margins of which are not inflected, or only partially so, and therefore one-celled, and the placentation parietal or free central, both ventral and dorsal sutures may be observed externally alternating with each other. The fruit, which is formed in a similar manner, necessarily presents a similar alternation of the sutures on its external surface.

Dehiscence.—The pericarp at varying periods, but commonly when the fruit is ripe, either opens, so as to allow the seed or seeds to escape; or it remains closed, and the seeds can then only become free by its rupture or decay. In the former case the fruit is said to be *dehiscent*; in the latter, *indehiscent*. Those fruits, such as the Nut, Cherry, Apple, and Date, which have very hard or fleshy pericarps, are usually indehiscent.

Dehiscent fruits open in various ways:—1st. By splitting longitudinally in the line of one or both of the sutures; or at the junction of the component ovaries only; or at these points as well as at the dorsal sutures. In all the above cases the pieces into which the fruit separates are called *valves*, and these valves, when the fruit is normal in its structure, are either equal in number to the cells, or component ovaries, or they are twice as numerous. Thus in fruits formed of a single carpel or ovary, which only open by the ventral (*fig.* 462) or dorsal (*fig.* 463) suture, there will be only one valve, corresponding to the one ovary, or its one cell; but if the carpels open by both sutures (*fig.* 464), there will be two valves. In fruits formed of compound ovaries with two or more cells, the valves will be equal in number to the cells or component ovaries, if the dehiscence only takes place by the dorsal suture (*figs.* 468–470), or in the line of union of the component ovaries (*figs.* 465–467); or they will be double the number, if the dehiscence takes place by both these parts. In compound one-celled fruits the valves will be equal in number to the component carpels, if the dehiscence occurs only by the ventral (*fig.* 475) or dorsal sutures (*fig.* 476); or double the number, if by both sutures. When there is a distinct axis left after the separation of the valves or carpels, this is called the *columella* (*fig.* 471, *a*). According to the number of valves, the fruit is described as *one-valved*, *two-valved*, *three-valved*, *four-valved*, *five-valved*, or *many-valved*.

FIG. 460.

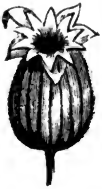


FIG. 461.

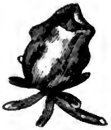


FIG. 462.

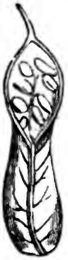


Fig. 460. Fruit of *Lychnis.*——*Fig.* 461. Fruit of Mignonette (*Reseda*).——*Fig.* 462. Follicle of Columbine (*Aquilegia*), dehiscing by ventral suture.

2nd. Dehiscence, instead of taking place longitudinally, or in a valvular manner, sometimes occurs in a transverse direction, by which the upper part of the fruit separates from the lower like the lid from a jar or box (*figs.* 479 and 480). And 3rd. It may take place in an irregular manner by little pores (*fig.* 482).

We have thus three kinds or classes of dehiscence, which are called respectively:—1. *Valvular*; 2. *Transverse* or *Circumscissile*; and 3. *Porous*.

1. Valvular Dehiscence.—This may be either partial or complete; thus, in *Lychnis* (*fig.* 460), and many other Caryophyllaceous plants, the dehiscence only takes place at the upper part of the fruit, which then appears toothed, the number of teeth corresponding to that of the valves in complete dehiscence. In the Mignonette a kind of partial dehiscence may also be seen (*fig.* 461) by which one large orifice is formed at the summit of the fruit at an early stage of its growth, that is, long before the seeds are ripe. At other times the separation of the fruit into valves is more or less complete, so that the nature of the dehiscence is at once evident. There are various modifications of these complete forms of valvular dehiscence. Thus, in fruits

Fig. 463.

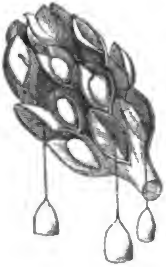


Fig. 464.

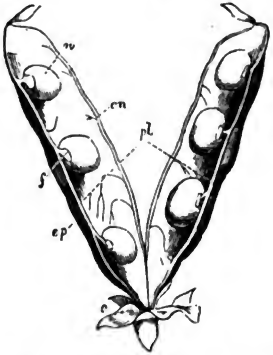


Fig. 463. Follicles of *Magnolia glauca*, dehiscing by their dorsal sutures. The seeds are suspended from the fruits by long stalks or funiculi.——*Fig.* 464. Legume of the Pea which has opened by both dorsal and ventral sutures; hence it is two-valved. *c.* Calyx. *ep.* Epicarp. *pl.* Placenta. *ov.* Seeds attached to the placenta by a funiculus or stalk, *f.* *en.* Endocarp.

which are formed of but one carpel or ovary, the dehiscence may take place by the ventral suture only, as in the Columbine (*fig.* 462); or by the dorsal suture only, as in some Magnolias (*fig.* 463); or by both dorsal and ventral sutures, as in the Pea (*fig.* 464), and most other Leguminous plants. This form of dehiscence is commonly known as *sutural.*

In compound fruits having two or more cells, and therefore with axile placentation, there are three principal kinds of dehiscence, which are called respectively, *septicidal*, *loculicidal*, and *septifragal.*

FIG. 465.

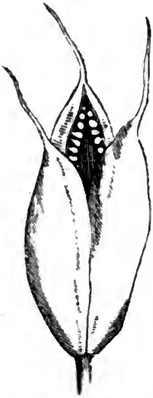


FIG. 466.

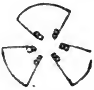


FIG. 467.

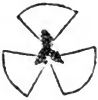


Fig. 465. Capsule of the Meadow Saffron (*Colchicum autumnale*), showing septicidal dehiscence.——*Fig.* 466. Diagram of septicidal dehiscence showing the placentas and seeds carried away with the valves.——*Fig.* 467. Diagram of septicidal dehiscence, showing the valves breaking away from a central column formed by the union of the placentas.

A. *Septicidal Dehiscence.*—In this the fruit is separated into its component ovaries or carpels by a division taking place between the two halves of each dissepiment (*figs.* 465–467). Examples may be seen in the *Colchicum* and *Rhododendron.* Here each valve corresponds to an ovary or carpel, and the valves are said to have their margins turned inwards. In this dehiscence the placentas with the seeds attached are either carried away with the valves (*fig.* 466), as in the *Colchicum*; or the valves break away from the placentas, which remain united and form a central column (*fig.* 467).

B. *Loculicidal Dehiscence.*—This is said to occur when each carpel or ovary opens by its dorsal suture,

FIG. 468.

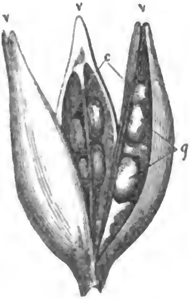


FIG. 469.

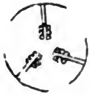


FIG. 470.

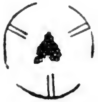


FIG. 471.

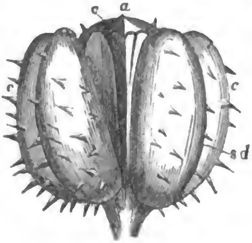


FIG. 472.

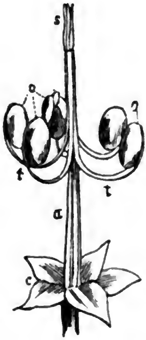


Fig. 468. Capsule of a species of ***Hibiscus***, dehiscing loculicidally. *v, v, v.* Valves. *c.* Dissepiments. *g.* Seeds.——*Fig.* 469. Diagram of loculicidal dehiscence, in which the valves bearing the dissepiments carry the placentas and seeds with them.——*Fig.* 470. Diagram of loculicidal dehiscence, in which the valves bearing the dissepiments have separated from the placentas, which remain as a central column with the seeds attached.——*Fig.* 471. Fruit of Castor-oil Plant (***Ricinus communis***), dehiscing in a septicidal manner. *c, c, c.* Carpels. *a.* Columella. *sd.* Dorsal suture where each carpel ultimately opens.——*Fig.* 472. Fruit of a species of ***Geranium***. *c.* Persistent calyx. *a* Axis or carpophore, from which the carpels, *o, o,* with their styles, *t, t,* are separating. *s.* Stigmas.

or through the back of the cells, the dissepiments remaining undivided (*figs.* 468–470). Here each valve is composed of the united halves of two adjoining ovaries or carpels, and the valves are said to bear the dissepiments in the middle. Examples may be seen in the Iris (*fig.* 502) and *Hibiscus* (*fig.* 468). In this kind of dehiscence, as in septicidal dehiscence, the valves may either carry the placentas and seeds with them (*fig.* 469), as in the *Hibiscus* and *Iris*; or they may break away from the placentas, and leave them united in the form of a central column (*fig.* 470).

In some forms of septicidal dehiscence the ovaries or carpels separate without opening, as in *Scrophularia* (*fig.* 501), in which case they may afterwards open by their dorsal sutures, that is, in a loculicidal manner. In other cases the axis is prolonged in the form of a columella, as in the Castor-oil Plant (*fig.* 471, *a*), or carpophore, as in the Geraniaceæ (*fig.* 472, *a*), and Umbelliferæ (*fig.* 506), and the carpels which are united to it also separate without their ovaries opening. The ovaries of such carpels frequently open afterwards by their dorsal sutures (*fig.* 471, *sd*). When such carpels separate with a certain amount of elasticity from the axis to which they are attached, as in certain of the Euphorbiaceæ, they have been called *cocci* (*fig.* 471, *c*, *c*, *c*); and the fruit is described as *dicoccous*, *tricoccous*, &c., according to their number. Others, again, call all fruits, the carpels of which separate from each other without opening, *schizocarps*; and term their component carpels *cocci* if there are more than two, as in the Geraniaceæ (*fig.* 472); or if only two in number, as in the Umbelliferæ (*fig.* 506), *mericarps*.

C. *Septifragal Dehiscence.*—In this form of dehiscence the ovaries or carpels open by their dorsal sutures, as in loculicidal dehiscence, and at the same time the dissepiments separate from the walls and remain united to each other and to the axis (*figs.* 473 and 474), which in this case is generally more or less prolonged. Here each valve is composed of the two halves of adjoining ovaries. This form of dehiscence may be seen in the *Datura* (*fig.* 473). The placentas bearing the seeds are here attached to the axis (*fig.* 474).

In compound fruits with one cell having parietal or free central placentation, we have two forms of dehiscence; these are analogous to the ordinary septicidal and loculicidal kinds just described. Thus, in compound fruits with parietal placentation, the dehiscence may take place either through the confluent margins or sutures of the adjoining ovaries or carpels, so that each placenta is divided into its two lamellæ, as in the Gentian (*fig.* 475), in which case the dehiscence is analogous to the septicidal form, and each valve therefore represents one of the component ovaries or carpels of the fruit; or the dehiscence may take place through the dorsal sutures, as in the Heartsease (*fig.* 476), in which case it is analogous to the loculicidal form of dehiscence, and each valve is composed of the adjoining

FIG. 473.

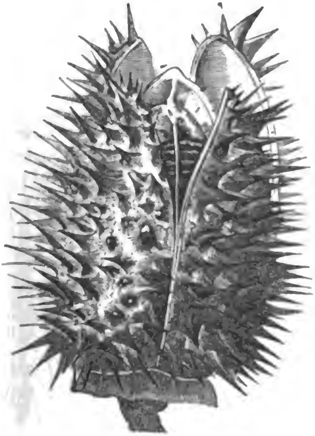


FIG. 474.

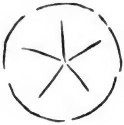


FIG. 475.

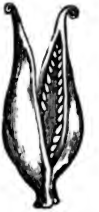


Fig. 473. Capsule of *Datura Stramonium*, showing septifragal dehiscence.——*Fig.* 474. Diagram illustrating septifragal dehiscence. *Fig.* 475. One-celled fruit of a species of Gentian dehiscing in a septicidal manner.

halves of two ovaries or carpels. These forms may be readily distinguished by the varying attachment of the placentas and seeds in the two cases; thus, in the former instance, each valve will bear the placentas and seeds on its two margins (*fig.* 475), and the valves are said to be *placentiferous at their borders*; in the latter, the placenta and seeds will be attached to the centre of each valve (*fig.* 476), and the valves are then said to be *placentiferous in their middle*. It sometimes happens, as in the fruit of the *Chelidonium* (*fig.* 478), and Wallflower (*fig.* 477), that the placentas bearing the seeds remain undivided, and the valves break away from them, so that they are left attached to a frame, which then receives the name of *replum*.

FIG. 476.

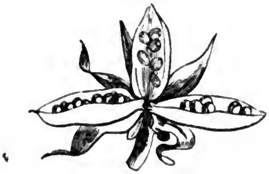


FIG. 477.

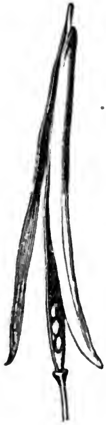


FIG. 478.

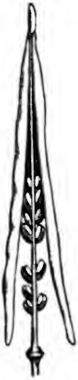


Fig. 476. One-celled fruit of Heartsease (*Viola tricolor*), dehiscing in a loculicidal manner.——*Fig.* 477. Fruit or siliqua of the Wallflower, showing the separation of two valves from the replum.——*Fig.* 478. Fruit of Celandine (*Chelidonium majus*), with the two valves separating from the replum.

In compound fruits with a free central placentation, the same forms of dehiscence occur as in those with parietal placentation, but here it is difficult in many cases to speak positively as to the nature of the dehiscence from the absence of seeds or dissepiments upon the valves. The means usually adopted in such cases is to count the number of the valves and compare their position with the sepals or divisions of the calyx. Thus, as the different whorls of the flower in a regular arrangement alternate with each other, the component carpels or ovaries of the fruit should alternate with the divisions or sepals of the calyx. If the fruit therefore separates into as many portions as there are parts or sepals to the calyx, and if these valves are then placed alternate to them, they represent the component carpels or ovaries, and the dehiscence is consequently analogous to the septicidal form; if, on the contrary, the valves are equal and opposite to the sepals or divisions of the calyx, each valve is composed of the adjoining halves of two ovaries or carpels, and the dehiscence is analogous to the loculicidal form. Sometimes the number of valves is double that of the calycine segments or sepals, in which case each valve is formed of half an ovary or carpel, the dehiscence of the fruit having taken place both by its dorsal and ventral sutures.

In all the above varieties of valvular dehiscence, the separation may either take place from above downwards (*figs.* 465, 468, and 473), which is by far the more usual form; or occasionally from below upwards, as in the Celandine (*fig.* 478), and in Cruciferous plants universally (*fig.* 477).

2. Transverse or Circumscissile Dehiscence.—In this kind of dehiscence the opening takes place by a transverse fissure encircling the pericarp, so that the upper part is separated from the lower, like the lid of a jar or box, as in the *Hyoscyamus* (*fig.* 479). Sometimes the dehiscence only takes place half round the fruit, as in *Jeffersonia*, in which case the lid remains attached to the pericarp on one side, as by a hinge.

In the Monkey-pot (*fig.* 480), the lower part of the ovary is adherent to the tube of the calyx, and the upper portion is free; and when dehiscence takes place, it does so in a transverse manner and at the part where the upper free portion joins the lower adherent one, so that it would appear as if the adherence of the calyx had some effect in this case in producing the transverse dehiscence.

Transverse dehiscence may also occur in fruits which are formed by a single ovary or carpel, as well as in the compound ones mentioned above. Thus, the fruits of *Coronilla*, *Hedysarum* (*fig.* 481), *Ornithopus*, &c., separate when ripe into as many portions as there are seeds.

FIG. 479.

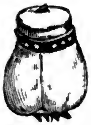


FIG. 480.

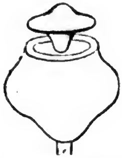


FIG. 481.

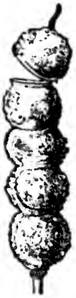


Fig. 479. Fruit of Henbane (*Hyoscyamus*) with transverse dehiscence. This fruit is termed a *pyxis*, which is the name given to a capsule with transverse dehiscence. *Fig.* 480. Fruit of the Monkey-pot (*Lecythis ollaria*), showing transverse dehiscence.——*Fig.* 481. Lomentum of a species of *Hedysarum* separating transversely into one-seeded portions.

3. POROUS DEHISCENCE.—This is an irregular kind of dehiscence, in which the fruits open by little pores or slits, formed in their pericarps. These openings may be either situated at the apex, side, or base of the fruit, hence they are described accordingly, as *apicular*, *lateral*, or *basilar*. Examples of this kind of dehiscence occur in the Poppy, in which a number of pores are placed beneath the stigmas; in the *Antirrhinum*, where there are two or three orifices, one of which is situated near the summit of the upper cell or ovary, and the other

(one or two) in the lower; and in various species of *Campanula* (*fig.* 482, *t*, *t*).

Kinds of Fruit.—A number of different kinds of fruit have been distinguished and named, and several classifications of the same have been proposed at various times, but at present there is little accordance among botanists upon this subject. In a work like the present it would be impossible to describe all the kinds of fruits which have received names. But at the same time, the subject is of too much importance to be hastily disposed of, and as much space as possible will be therefore devoted to its consideration. The classification here adopted is founded upon that given many years since in Lindley's *Introduction to Botany*, from which, however, it differs in some important particulars. We have taken the gynœcium as our guide, and have accordingly used the terms when applied to fruits in precisely the same sense as previously defined in its description.

FIG. 482.

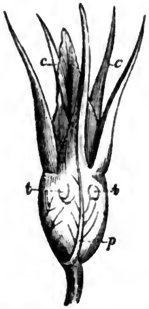


Fig. 482. Immature fruit of a species of *Campanula*. *p*. Pericarp. *t*, *t*. Pores at the sides. *c*, *c*. Persistent calyx united below to the wall of the fruit so as to form a part of the pericarp.

The leading divisions of the classification here adopted are as follows:—

1. Fruits formed by a Single Flower.
    - *a*. Simple Fruits.
    - *b*. Apocarpous Fruits.
    - *c*. Syncarpous Fruits.
2. Fruits formed by the combination of Several Flowers.

1. Fruits formed by a Single Flower.

a. Simple Fruits.—*By a simple fruit, we mean one which is formed of a single mature carpel or ovary, and only one produced by a single flower.* We shall describe the three more important kinds of simple fruits:—namely, the Legume, the Lomentum, and the Drupe.

1. *Legume or Pod.*—This is a superior, one-celled, one or many-seeded fruit, dehiscing by both ventral and dorsal sutures, so as to form two valves, and bearing its seed or seeds on the ventral suture. Examples occur in the Pea (*fig.* 464), and most plants of the order Leguminosæ, which derives its name from that circumstance. The legume assumes a variety of forms, but it is generally more or less convex on its two surfaces and nearly straight; at other times, however, it becomes contorted so as to resemble a screw (*fig.* 485), or a snail twisted, as in some species of *Medicago* (*fig.* 484), or it is coiled up like a caterpillar, as in *Scorpiurus sulcata* (*fig.* 483), or it assumes a number of other irregular forms. Certain deviations from the ordinary structure of a legume are also met with in some plants; thus, in *Astragalus* and *Phaca* it is two-celled, in consequence

FIG. 483.

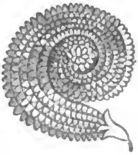


FIG. 484.

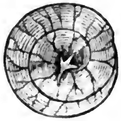


FIG. 485.

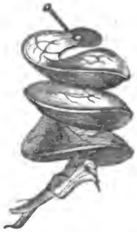


Fig. 483. Coiled-up legume of *Scorpiurus sulcata.*——*Fig.* 484. Snail-like legume of *Medicago orbiculata.*——*Fig.* 485. Spiral or screw-like legume of Lucerne (*Medicago sativa*).

of the formation of a spurious dissepiment, which in the first plant proceeds from the dorsal suture, and in the latter from the ventral. At other times a number of spurious horizontal dissepiments are formed, by which the legume becomes divided into as many cells as there are seeds, as in the *Cassia Fistula* (*fig.* 487). In some cases also, as in the latter plant, the legumes are indehiscent.

2. *The Lomentum.*—This differs from the legume by being contracted in a moniliform manner between each seed, as in the *Hedysarum* (*fig.* 481), and *Acacia Sophora* (*fig.* 486). This fruit, together with the legume, characterise the plants of the Leguminosæ. When the lomentum is ripe, it either separates into as many pieces as there are contractions on its surface (*fig.* 481), or it remains entire (*fig.* 486); in the latter case the seeds are separately enclosed in cavities which are formed by the production of as many internal spurious dissepiments as there are external contractions.

FIG. 486.

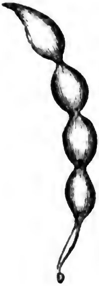


FIG. 487.

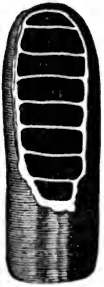


FIG. 488.

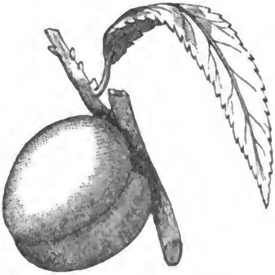


Fig. 486. Lomentum of a species of *Acacia.*——*Fig.* 487. Vertical section of a portion of the fruit of *Cassia Fistula*, showing a number of transverse spurious dissepiments.——*Fig.* 488. Drupe of the Peach.

3. *The Drupe.*—This is a superior, one-celled, one or two-seeded, indehiscent fruit, having a fleshy or pulpy sarcocarp, a hard or bony endocarp, and the whole pericarp readily separable into epicarp, sarcocarp, and endocarp, as in the Peach (*figs.* 488 and 489) and Cherry (*fig.* 490). Any fruit which resembles the drupe in its general characters is frequently termed *drupaceous* or *drupe-like.*

b. APOCARPOUS FRUITS.—*Under this name we include those fruits which are formed of a single mature carpel or ovary, but of which two or more are produced by a single flower.* We describe three kinds of Apocarpous fruits:—The Follicle, the Achænium, and the Etærio.

FIG. 489.

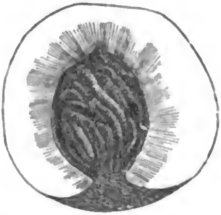


FIG. 490.

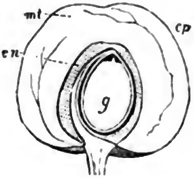


Fig. 489. Drupe of the Peach cut vertically.——*Fig.* 490. Vertical section of the drupe of the Cherry. *cp.* Epicarp. *en.* Endocarp. *mt.* Mesocarp. *g.* Seed with embryo.

1. *The Follicle.*—This is a superior, one-celled, one- or many-seeded fruit, dehiscing by the ventral suture only, and consequently one-valved (*fig.* 462). By the latter character it is known at once from the legume, which opens, as we have seen, by two sutures, and is two-valved; in other respects the two fruits are alike. In *Magnolia glauca* (*fig.* 463), and some other species of *Magnolia*, the follicle opens by the dorsal suture instead of the ventral. Examples of the follicle occur in the Columbine (*figs.* 462 and 491), Aconite (*fig.* 492), and *Magnolia* (*fig.* 463).

2. *The Achænium* or *Achene* is a superior, one-celled, one-seeded fruit, with a dry indehiscent pericarp, which is separable from the seed, although closely applied to it. Such fruits may be generally distin-

FIG. 491.

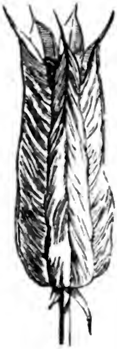


FIG. 493.

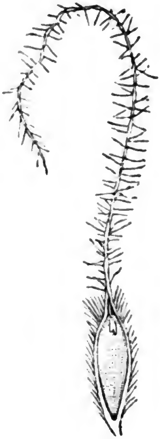


FIG. 492.

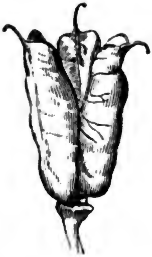


FIG. 494.

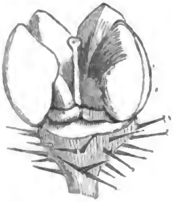


Fig. 491. Follicles of the Columbine (*Aquilegia*).——*Fig.* 492. Follicles of the Aconite (*Aconitum*).——*Fig.* 493. Vertical section of an achænium of the Pasque-flower (*Anemone Pulsatilla*). The fruit in this instance is said to be tailed in consequence of being surmounted by a feathery style.——*Fig.* 494. Achænia of Bugloss (*Lycopsis*).

guished from seeds, with which, on account of their small size, they are frequently confounded, by presenting on some point of their surface the remains of the style. This style is in some cases very evident, as in the Anemone (*fig.* 493). Examples may be seen in the Clematis and Anemone, and in the plants of the orders Labiatæ and Boraginaceæ (*fig.* 494).

3. *The Etærio.*—When the achænia borne by a single flower are so numerous that they form more than a single whorl or series, they constitute collectively an *etærio*. Examples may be seen in the species of *Ranunculus*, where the achænia are placed upon a convex thalamus of a dry nature; and in the Strawberry (*fig.* 495), where they are situated upon a fleshy thalamus.

FIG. 495.

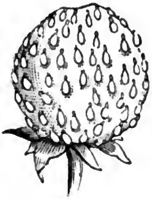


FIG. 496.

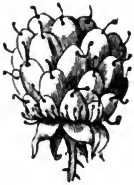


Fig. 495. Fruit of the Strawberry.——*Fig.* 496. Fruit (*etærio*) of the Raspberry (*Rubus Idæus*).

In the Raspberry (*fig.* 496) and Bramble we have a kind of etærio formed of a number of little drupe-like fruits, or drupels as these small fruits are sometimes termed, crowded together upon a dry thalamus.

In the fruit of the Rose the achænia, instead of being placed upon an elevated thalamus, as in the ordinary etærio, are situated upon a concave thalamus, to which the calyx is attached (*fig.* 324). This modification of the ordinary etærio has been made a separate fruit by some botanists, to which the name *Cynarrhodum* has been given.

c. Syncarpous Fruits.—*Under this head we include all fruits which are formed by the more or less complete combination of two or more mature ovaries or carpels, and where only one fruit is produced by a single flower.* In the two former classes the fruits are formed of simple ovaries; in this class from ovaries of a more or less compound nature. In describing these fruits they are first arranged, from their superior or inferior character, in two divisions; and then each of these divisions is again separated into others, derived from the dry or fleshy nature of their pericarp, and its dehiscent or indehiscent nature.

Division 1. *Superior Syncarpous Fruits.*

a. WITH A DRY INDEHISCENT PERICARP.

1. *The Caryopsis* is a superior, one-celled, one-seeded, indehiscent fruit, with a thin dry membranous pericarp, completely and inseparably united with the seed (*figs.* 497 and 498). This fruit resembles the

Fig. 497.

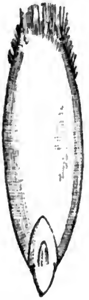


Fig. 498.

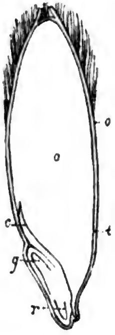


Fig. 499.

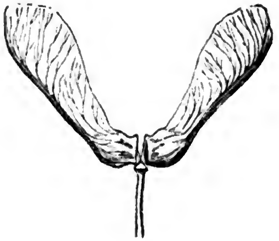


Fig. 497. Caryopsis or fruit of the Oat.——*Fig.* 498. The same, cut vertically. *o.* Pericarp. *t.* Integuments of the seed. *a.* Albumen or endosperm. *c.* Cotyledon. *g.* Plumule. *r.* Radicle.——*Fig.* 499. Samara or fruit of the Maple.

achænium, but it is distinguished by the complete union which exists between the pericarp and the seed. It is, moreover, generally considered as being of a compound nature, from the presence of two or more styles and stigmas on the ovary from which it is formed (*fig.* 422). It is found generally in the Grass order.

2. *The Samara* is a superior, two or more celled fruit, each cell being dry, indehiscent, few-seeded, and having its pericarp extended into a winged expansion. Each cell of the samara is in fact a winged achænium. Examples may be found in the Maple (*fig.* 499), Ash, and Elm. By some botanists each winged portion of such a fruit is called a samara, and thus such fruits as the Maple are considered to be formed of two united samaræ.

FIG. 500.

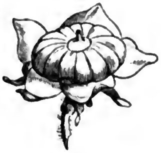


Fig. 500. Carcerule or fruit of the Mallow (*Malva*).

3. *The Carcerule* is a superior, many-celled fruit, each cell being dry, indehiscent, and one- or few-seeded, and all the cells more or less cohering by their united styles to a central axis. The common Mallow (*fig.* 500) is a good example of this fruit. Each cell of the carcerule does not differ essentially from an achænium.

b. WITH A DRY DEHISCENT PERICARP.

1. *The Capsule* is a superior, one or more celled, many-seeded, dry, dehiscent fruit. The dehiscence may either take place by valves, as in *Colchicum* (*fig.* 465); or by pores, as in the Poppy; or *transversely*, as in Henbane (*fig.* 479); or only *partially*, as in Mignonette (*fig.* 461), and *Lychnis* (*fig.* 460). When the capsule dehisces transversely, as in the Henbane (*fig.* 479), the fruit has received the distinctive name of *Pyxis.* The capsule is either one-celled, as in the Mignonette (*fig.*

461); or two-celled, as in the *Scrophularia* (*fig.* 501); or three-celled, as in the *Colchicum* (*fig.* 465); or more than three, as in *Datura* (*fig.* 473). The capsule is a very common fruit, and is found almost universally in many natural orders, as Papaveraceæ, Caryophyllaceæ, Primulaceæ, Scrophulariaceæ, Gentianaceæ, &c., &c.

FIG. 501.

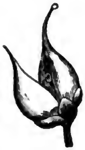


FIG. 502.

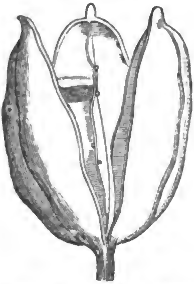


FIG. 503.

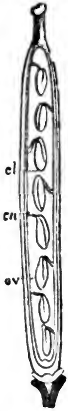


Fig. 501. Fruit or capsule of a species of *Scrophularia*, dehiscing in a septicidal manner.——*Fig.* 502. Capsular fruit (*diplotegia*) of the Iris, opening in a loculicidal manner.——*Fig.* 503. Vertical section of the ovary of the Wallflower. *ov.* Ovules, each attached by a stalk to the placenta, *cn.* *cl.* Vertical spurious dissepiment called the *replum.*

When a fruit resembles the ordinary capsule in every respect, except that it is inferior, as in the species of *Iris* (*fig.* 502) and *Campanula*, it has received the name of *Diplotegia.* In descriptive botany such a fruit is commonly termed *capsular.*

2. *The Siliqua* is a superior, one- or two-celled,

many-seeded, long, narrow fruit, dehiscing by two valves separating from below upwards, and leaving the seeds attached to two parietal placentas, which are commonly connected together by a spurious vertical dissepiment, called a *replum* (*fig.* 477). The placentas are here opposite to the lobes of the stigma, instead of alternate, as is the case in all fruits which are regular in structure. When the replum extends entirely across the cavity, the fruit is two-celled; if only partially, it is one-celled. Examples of this fruit occur in the Wallflower (*figs.* 477 and 503), and a large number of other Cruciferæ. When a fruit possesses the general characters of the siliqua, but with the lobes of the stigma alternate to, instead of opposite, the placentas, as in *Chelidonium* (*fig.* 478), it has been named a *Ceratium* or a *siliquæform capsule.*

The siliqua is sometimes contracted in the spaces between each seed, like the lomentum (page 289) in which case it is indehiscent, as in *Raphanus sativus*, and is then called a *lomentaceous siliqua.*

FIG. 504.

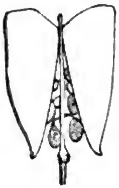


Fig. 504. Silicula of Shepherd's Purse (*Thlaspi*).

3. *The Silicula.* — This fruit resembles the siliqua in every respect except as to its length; and in usually containing fewer seeds. Thus the *siliqua* may be described as long and narrow, the *silicula* as broad and short. Examples occur in the Shepherd's Purse (*fig.* 504), and many other Cruciferæ.

The siliqua and silicula are only found in plants of the order Cruciferæ. Both fruits are occasionally one-seeded, and indehiscent.

c. WITH A FLESHY INDEHISCENT PERICARP.

The Hesperidium is a superior, many-celled, few-seeded, indehiscent fruit, consisting of a separable rind, formed of the epicarp and mesocarp combined together (*fig.* 505, *p*, *e*), and having an endocarp, *d*, projecting internally in the form of membranous partitions, which divide the pulp into a number of portions or cells, which are easily separated from each other. The seeds, *s*, *s*, are imbedded in the pulp, and attached to the inner angle of each of the portions into which the fruit is divided. The fruits of the Orange, Lemon, Lime, Shaddock, and others derived from the genus *Citrus*, are examples of the hesperidium.

FIG. 505.

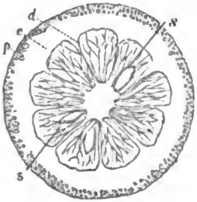


Fig. 505. Transverse section of the fruit of the Orange (*Citrus Aurantium*). *p.* Epicarp. *e.* Mesocarp. *d.* Endocarp. *s*, *s.* Seeds.

Division 2. Inferior Syncarpous Fruits.

a. WITH A DRY INDEHISCENT PERICARP.

1. *The Cremocarp* is an inferior, dry, indehiscent, two-celled, two-seeded fruit. The two cells or halves of which this fruit is composed are joined face to face to a common axis or *carpophore*, from which they separate when ripe, but to which they always remain attached by a slender cord which suspends them (*fig.* 506). Each half-fruit is termed a *hemicarp* or *mericarp*, and the inner face the *commissure*. Each portion of the fruit resembles an achænium, except in being inferior; hence the name *diachænium* has been given to this fruit. Examples of the cremocarp as above defined, are found universally in the plants of the order Umbelliferæ, but in no other order.

FIG. 506.

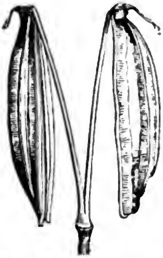


Fig. 506. Cremocarp or fruit of *Angelica.*

2. *The Cypsela.*—This differs in nothing essential from the achænium, except in being inferior and of a compound nature. It occurs in all plants of the order Compositæ.

3. *The Glans* or *Nut* is an inferior, dry, hard indehiscent, one-celled, one- or two-seeded fruit, produced from an ovary of two or more cells, with one or more ovules in each cell, all of which become abortive in the progress of growth except one or two. The three layers constituting the pericarp of the nut are firmly coherent and undistinguishable, and the whole is more or less enclosed by a *cupule*. The Acorn (*fig.* 282), and the Hazel-nut (*fig.* 283), may be taken as examples.

b. WITH A FLESHY INDEHISCENT PERICARP.

1. *The Bacca* or *Berry* is an inferior, indehiscent, one or more celled, many-seeded, pulpy fruit (*figs.* 507 and 508). The pulp is produced from the placentas, which are parietal (*fig.* 507, *pl*), and have the seeds, *s*, *s*, at first attached to them; but these become ultimately separated and lie loose in the pulp, *p*. Examples may be found in the Gooseberry and Currant.

FIG. 507.

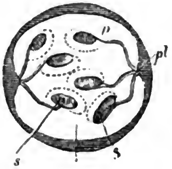


FIG. 508.

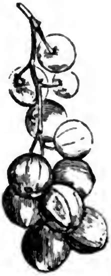


FIG. 509.

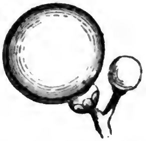


Fig. 507. Transverse section of a berry of the Gooseberry (*Ribes Grossularia*). *pl.* Placentas. *s*, *s*. Seeds imbedded in pulp, *p*. *Fig* 508. Raceme of berries of the Red Currant (*Ribes rubrum*). ——*Fig.* 509. Nuculanium or fruit of the Vine (*Vitis vinifera*).

The fruit of the Grape is sometimes called a Nuculanium (*fig.* 509), but it differs in nothing essential from the berry, except in being superior. The name *baccate* or *berried* is applied by many botanists to any fruit of a pulpy nature.

2. *The Pepo* is an inferior, one-celled, or spuriously three-celled (*fig.* 510), many-seeded, fleshy or pulpy fruit. The seeds are attached to parietal placentas, and are imbedded in pulp, but they never become loose as is the case in the berry; and hence this fruit is readily distinguished from it.

FIG. 510.

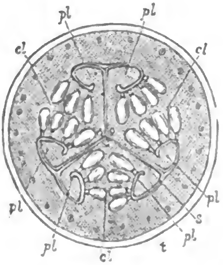


FIG. 511.

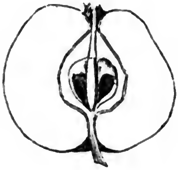


Fig. 510. Transverse section of the fruit or pepo of the Melon. *cl, cl, cl.* Carpels. *pl, pl, pl, pl, pl, pl.* Curved placentas, sending processes, *s*, from the circumference, *t*, to the centre, and thus causing the fruit to be spuriously three-celled.——*Fig.* 511. Vertical section of the pome or fruit of the Apple (*Pyrus Malus*).

3. *The Pome* is an inferior, indehiscent, two or more celled, few-seeded, fleshy fruit; the endocarp of which is papery, cartilaginous, or bony, and surrounded by a fleshy mass consisting of mesocarp and epicarp, which is generally considered to be formed by the cohesion of the general parenchyma of the ovary with the tube of the calyx. Some botanists, however, regard the fleshy portion as consisting of the enlarged end of the flower-stalk, in which the true carpels are imbedded. Examples may be seen in the Apple (*fig.* 511), Quince (*fig.* 340), and Medlar.

2. FRUITS FORMED BY THE COMBINATION OF SEVERAL FLOWERS.

These fruits have been termed *Anthocarpous*, as they consist not only of the mature carpels or ovaries of several flowers united, but also usually of the bracts and floral envelopes in combination with them,—that is to say, the whole inflorescence is blended to form a fruit. They have been also called *Multiple*, *Collective*, and *Infrutescences* or *Confluent Fruits*. Such fruits have been likewise termed *polythalamic*, to distinguish them from fruits formed from single flowers, which are called *monothalamic*. The following may be mentioned :—

1. *The Cone* is a more or less elongated fruit, composed of a number of indurated scales, each of which bears one or more naked seeds. This fruit is seen in the Scotch Fir (*fig.* 512), Larch, Hemlock Spruce (*fig.* 299), and a great many other plants of the order Coniferæ, which derives its name from this circumstance. There are two views as to the nature of the indurated scales: by some botanists they are regarded as carpels spread open, by others as bracts. They certainly more resemble the latter organs in appearance, as they never present any trace of style or stigma on their surface. Some botanists regard the cone as the *spurious fruit* (page 271) or *pseudocarp* of a single flower, and not as a collection of fruits, as here described.

FIG. 512.

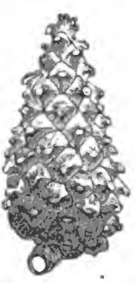


Fig. 512. Cone or fruit of the Scotch Fir.

2. *The Galbulus.*—This fruit is but a modification of the Cone; differing only in being more or less rounded in form instead of somewhat conical, and in having the heads of the scales much enlarged. It is seen in the Cypress (*fig.* 514), and in the Juniper (*fig.*

513). In the latter the scales become fleshy, and are united together into one mass, so that it somewhat resembles at first sight a berry, but its nature is at once seen by examining the apex, when three radiating lines will be observed corresponding to the three scales of which the fruit has been formed, and which are here but imperfectly united.

No other kind of fruits except the Cone and Galbulus are found in the natural orders Coniferæ and Cycadaceæ, the so-called fruit (*sphalerocarpium*) of the Yew being simply a naked seed surrounded, except at the apex, by a fleshy cup or aril.

3. *The Strobilus or Strobile.*—The fruit of the Hop (*fig.* 300) is by some botanists considered as a kind of Cone with membranous scales, to which the name of *Strobilus* or *Strobile* has been given; but the strobile differs essentially from the cone, in having its seed distinctly enclosed in a carpel placed at the base of each scale. It should be also noticed that the term *Strobilus* is also frequently employed as synonymous with *Cone.*

FIG. 513.

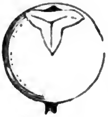


FIG. 514.

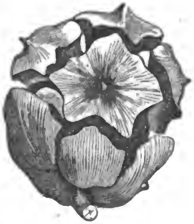


FIG. 515.

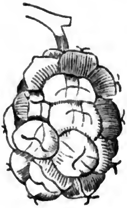


Fig. 513. Galbulus or fruit of the Juniper (*Juniperus communis*). ——*Fig.* 514. Galbulus or fruit of the Cypress (*Cupressus sempervirens*).——*Fig.* 515. Sorosis or fruit of the Mulberry (*Morus nigra*).

4. *The Sorosis* is a collective fruit, formed of a number of separate flowers firmly coherent into a fleshy or pulpy mass with the floral axis upon which they are situated. An example of this fruit may be seen in the

Pineapple (*fig.* 278), where each square portion represents a flower; and the whole is surmounted by a crown of empty bracts. The Mulberry (*fig.* 515) is another well-known fruit, which presents an example of the sorosis.

5. *The Syconus* is a collective fruit, formed of an enlarged and more or less succulent receptacle, which bears a number of separate flowers (*fig.* 288). The Fig is an example of a syconus. In this, the flowers are almost entirely enclosed by the enlarged hollow pear-shaped receptacle, and what are commonly called seeds are in reality one-seeded fruits resembling achænia.

Section 6. THE OVULE AND SEED.

HAVING now described the nature, structure, and general characters of the gynœcium or unimpregnated pistil, and the fruit or fertilised gynœcium, we pass to the description of the bodies contained respectively within them, namely, the Ovule and Seed.

1. THE OVULE.

The ovule is a small pulpy body, borne by the placenta, and which when fertilised becomes the seed. It is either attached directly to the placenta, when it is said to be *sessile* (*figs.* 28, *o*, *o*, and 439, *g*), or indirectly by a stalk called the *funiculus* (*fig.* 503, *ov*), when it is described as stalked. The point of attachment of the ovule to the placenta if sessile, or to the funiculus when stalked, is termed the *hilum.*

The ovules are commonly enclosed in an ovary (*fig.* 28, *o*, *o*), but all plants of the Coniferæ, Cycadaceæ, and allied orders are exceptions to this; thus in the Cycadaceæ they are situated on the margins of leaves in a peculiarly metamorphosed condition, and in the Coniferæ at the base of indurated bracts or open carpellary leaves (*fig.* 516, *ov*). Such ovules are therefore termed *naked*, and as the seeds of these plants are also naked, such plants are called *Gymnospermous*; while those plants in which the ovules are distinctly enclosed in an ovary, are called *Angiospermous*. It should be noticed, however, that there are some plants in which the seeds become partially naked in the course of the development of the ovary into the fruit, as in the Mignonette (*fig.* 461); these should be carefully distinguished from true Gymnospermous plants, or those in which the ovules are naked from their earliest formation, as the latter character is always associated with important structural peculiarities in the plants themselves, as we have already noticed in treating of the stem and other organs. Other important differences will also be described hereafter, and more especially in the Physiological part of this volume, under the head of Reproduction of Gymnospermia.

FIG. 516.

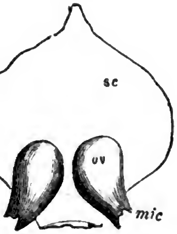


Fig. 516. Bract or carpellary leaf, *sc*, of a species of *Pinus*, bearing two naked ovules, *ov*, at its base. *mic.* Micropyle.

NUMBER AND POSITION OF THE OVULES.—*a. Number.*—The number of ovules in the ovary, or in each of its cells, varies in different plants. Thus in the Polygonaceæ, the ovary contains but a solitary ovule; and in the Umbelliferæ there is but one ovule in each cell. When there is more than one ovule in the ovary, or in each of its cells, the number may be either few or definite, in which case the number is indicated; or the ovules may be very numerous, when they are said to be *numerous* or *multiovulate*, as in *Viola* (*fig.* 28, *o*, *o*).

b. Position.—The position of the ovules with regard to the cavity or cell in which they are placed is also liable to vary. Thus when there is but one ovule, this may arise at the bottom of the ovary or cell and be directed towards the summit, as in the Compositæ, when it is said to be *erect*; or it may be inserted at the summit of the ovary and be turned downwards (*fig*. 517), in which case it is *inverse* or *pendulous*; or if it is attached a little above the base, and directed obliquely upwards (*fig*. 518), it is *ascending*; or if, on the contrary, it arises a little below the summit, and is directed obliquely downwards (*fig*. 519), it is *suspended*; or if from the side of the ovary, without turning upwards or downwards, as in *Crassula*, it is *horizontal* or *peltate*.

FIG. 517.

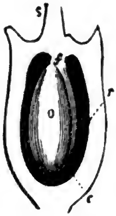


FIG. 518.

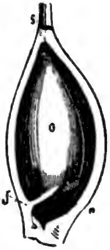


FIG. 519.

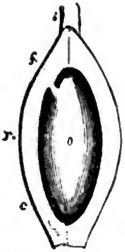


Fig. 517. Vertical section of the ovary of the Mare's Tail (*Hippuris vulgaris*). *o*. Ovule, which is inverse or pendulous, and anatropous. *s*. Base of the style. *f*. Funiculus. *r*. Raphe. *c*. Chalaza. ——*Fig*. 518. Vertical section of the ovary of the Pellitory (*Parietaria officinalis*), with a single ascending ovule.——*Fig*. 519. Vertical section of the ovary of the Mezereon (*Daphne Mezereum*), containing a solitary suspended ovule. The letters in the two last figures have the same references as in the previous one.

When the ovary or cell has two ovules, these may be either placed side by side at the same level, and have the same direction, when they are said to be *collateral*; or they may be placed at different heights, and then they may either follow the same direction, when they are *superposed*; or one ovule may be ascending and the other suspended. The position of the ovules in those cases where they are in definite numbers, is also usually constant and regular, and similar terms are employed; but when the number of ovules in the ovary or cell is indefinite, the relations are less constant, and depend in a great measure upon the shape of the cell and the size of the placentas.

DEVELOPMENT AND STRUCTURE OF THE OVULE.—The ovule first appears on the placenta as a little roundish cellular projection, which gradually enlarges and ultimately acquires a more or less ovate, oval, or somewhat conical form, and constitutes ultimately the *nucleus* (*fig.* 520) of the ovule. This nucleus is at first perfectly uniform in texture and appearance, presenting no cavities except those of the ordinary parenchymatous cells of which it is composed, and having no integuments; but as development proceeds a special cavity is formed at or near its apex (*figs.* 521, *c*, and 524, *b*), in which the embryo or future plant is developed; hence this cavity is called the *embryo-sac.* In rare cases, as in the Mistletoe, two or three embryo-sacs are formed. This sac is produced by the special development of one of the cells lying near the centre of the nucleus, which as it continues to increase in size presses upon the surrounding parenchymatous cells, and occasions their more or less complete absorption. Thus it sometimes causes the almost entire absorption of the nucleus, and even projects beyond it, either through the opening in its coats afterwards to be described, called the *micropyle* (*fig.* 524, *e*), or through its sides in various directions, by which one or more saccate processes are formed. More usually, however, the tissue of the nucleus is not entirely absorbed, but a portion is left surrounding the embryo-sac. The sac contains at first an abundance of semifluid protoplasmic matter, in which, before fertilisation takes place, two rounded or oval large nucleated cells are formed at its apex, which have been termed the *germinal* or *embryonic vesicles*; or, less frequently, one, three, or more of these make their appearance. Different views are entertained of the structure of these bodies. Thus, they are now almost universally regarded as simply nucleated masses of protoplasm, or, in other words, *primordial cells*; while a few believe that this protoplasm and nucleus are, at least in some cases, surrounded by a cell-wall formed of cellulose, as the ordinary cells of plants. Besides these germinal vesicles, the embryo-sac usually contains, before fertilisation has been accomplished, two or more small nucleated cells, which have been called *antipodal cells*, from being commonly situated at the opposite end of the sac to the germinal vesicles, that is, at its base. The purport of these cells is unknown, but their existence is temporary, as they disappear after fertilisation.

Some ovules, as those of the Mistletoe (*fig.* 520),

FIG. 520. FIG. 521. FIG. 522. FIG. 523.

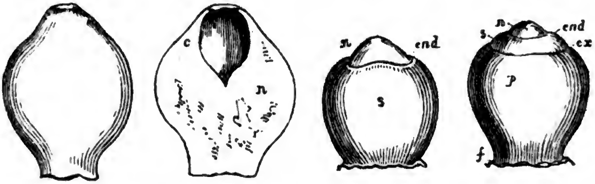


Fig. 520. Ovule of the Mistletoe (*Viscum album*), consisting of a naked nucleus.——*Fig.* 521. The same ovule cut vertically to show the embryo-sac, *c*, in the nucleus, *n*.——*Fig.* 522. Ovule of the Walnut (*Juglans regia*). *n*. Projecting end of the nucleus. *s*. Coat covering the nucleus except at the foramen, *end*.——*Fig.* 523. Ovule of a species of *Polygonum*. *f*. End of ovule where it is attached to the placenta. *p*. Primine. *s*. Secundine. *ex*. Exostome. *end*. Endostome. *n*. Projecting end of nucleus.

consist simply of the nucleus, *n*, and embryo-sac, *c*, as above described, in which case the nucleus is termed *naked*; but in almost all plants the nucleus becomes enclosed in one or two coats. Thus, in some cases, there is but one coat, which appears at first as a little circular process around its base; this gradually increases in size, and by growing upwards ultimately entirely closes the nucleus except at the apex, where a small opening may be always observed (*fig.* 522, *end*). The coat thus formed, where there is but one, is called the *integumentum simplex*, *s*, and the orifice, *end*, at the apex of the nucleus, *n*, is termed the *micropyle* or *foramen*.

In most plants, however, the ovule has two coats, in which case we observe two circular or annular processes around the base of the nucleus, the inner one being first developed; these processes continue to grow upwards as before described, until they also ultimately form two coats both of which entirely enclose the nucleus except at its apex (*fig.* 523). The inner coat is usually termed the *secundine* (*figs.* 523, *s*, and 524, *c*), and the outer the *primine* (*figs.* 523, *p*, and 524, *d*); and the orifice left at the apex of the nucleus, as in the former instance where only one coat is present, is called the *foramen* or *micropyle* (*fig.* 524, *e*). The openings in the two coats, with rare exceptions, correspond to each other, but it is sometimes found convenient to distinguish them by distinct names; thus, that of the outer is called the *exostome* (*fig.* 523, *ex*), and that of the inner, *endostome*, *end*.

FIG. 524.

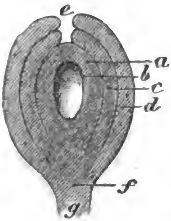


FIG. 525.

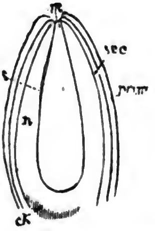


FIG. 526.

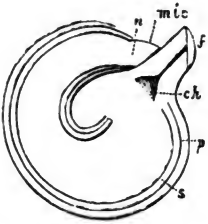


Fig. 524. Section of an ovule (diagrammatic). *a.* Nucleus. *b.* Embryo-sac. *c.* Inner coat. *d.* Outer coat. *e.* Micropyle. *f.* Chalaza. *g.* Funiculus. ——*Fig.* 525. Vertical section of the orthotropous ovule of *Polygonum*. *ch.* Chalaza. *prim.* Primine. *sec.* Secundine. *n.* Nucleus. *s.* Embryo-sac. *m.* Micropyle.——*Fig.* 526. Vertical section of a campylotropous ovule of Wallflower. *f.* Funiculus. *ch.* Chalaza. *p.* Primine. *s.* Secundine. *n.* Nucleus. *mic.* Micropyle or foramen.

The nucleus and its coat or coats are intimately connected at one point by a cellulo-vascular cord or layer, called the *chalaza* (*figs.* 524, *f*, and 525, *ch*); but at the other parts of the ovule they are more or less distinct. This chalaza is the point where the vessels pass from the placenta, or when the ovule is stalked from the funiculus, into the ovule, for the purpose of affording nourishment to it; it is generally indicated by being coloured, and of a denser texture than the tissue by which it is surrounded. The chalaza is by some considered as the organic base of the ovule, and the micropyle as the organic apex; but it is better to speak of the hilum as the organic base of the ovule, and the chalaza as the base of the nucleus.

The development and structure of the ovules as described above refer only to those of Angiospermous plants; but those of the Gymnospermia present some very striking differences, which will be described hereafter when speaking of their reproduction.

Relation of the Hilum, Chalaza, and Micropyle to one another.—When an ovule is first developed, the chalaza, or point of union of its coats and nucleus, is at the base or hilum, close to the placenta or funiculus; in which case a straight line would pass from the micropyle through the axis of the nucleus and its coats to the hilum. In rare instances this relation of parts is preserved throughout its development (*fig.* 525), when the ovule is termed *orthotropous.* In such an ovule, therefore, the micropyle (*fig.* 525, *m*) would be situated at its geometrical apex, or at the end farthest removed from the hilum, in which case the organic apex would correspond with the geometrical apex; while the chalaza, *ch*, would be placed at the base of the ovule or hilum.

It generally happens, however, that the ovule, instead of being straight as in the above instance, becomes more or less curved, or even altogether inverted. Thus in the Cruciferæ (*fig.* 526), the apex of the ovule becomes gradually turned downwards towards its base, and is ultimately placed close to it, so that the whole ovule is bent upon itself, and a line drawn from the micropyle, *mic*, through the axis of the nucleus, *n*, and its coats, would describe a curve; hence such ovules are called *campylotropous* or *curved*. In these ovules, the chalaza, *ch*, and hilum correspond as in orthotropous ones; but the micropyle, *mic*, instead of being at the geometrical apex of the ovule, is brought down close to the hilum or base.

In a third class of ovules the relative positions of parts is exactly the reverse of that of orthotropous ones—hence such are called *anatropous* or *inverted*. This arises from an excessive development of the ovule on one side, by which the chalaza (*fig*. 527, *ch*) is removed from the hilum, *h*, to the geometrical apex of the ovule; the micropyle, *f*, being at the same time turned towards the hilum, *h*. In anatropous ovules a connexion is always maintained between the chalaza and the hilum by means of a vascular cord or ridge called the *raphe* (*fig*. 527, *r*). A fourth kind of ovule is also sometimes distinguished under the name of *amphitropous*. In this ovule, which is likewise called *heterotropous* or *transverse*

FIG. 527.

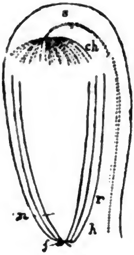


FIG. 528.

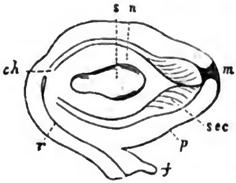


Fig. 527. Vertical section of the anatropous ovule of the Dandelion. *h*. Hilum. *f*. Micropyle or foramen. *n*. Nucleus, *s*. Base of the nucleus. *ch*. Chalaza. *r*. Raphe.——*Fig*. 528. Longitudinal section of the amphitropous ovule of *Lemna trisulca*. *f*. Funiculus. *n*. Nucleus. *p*. Primine. *sec*. Secundine. *s*. Embryo-sac. *ch*. Chalaza. *m*. Micropyle. *r*. Raphe.

(*fig.* 528), the hilum, *f*, is on one side, and the micropyle, *m*, and chalaza, *ch*, placed transversely to it, and the hilum connected to the chalaza by a short raphe, *r*.

2. THE SEED.

NATURE AND GENERAL CHARACTERS OF THE SEED AS COMPARED WITH THE OVULE.—The seed is the fertilised ovule. Like the ovule, it is either attached directly to the placenta, in which case it is described as *sessile*; or by means of a stalk, called the *funiculus* (*figs.* 463, 464, *f*, and 529, *f*), when it is said to be *stalked*; its point of attachment is also termed the *hilum*. The position of this hilum may be commonly seen on seeds which have separated from the funiculus or placenta, by the presence of a scar, or in a difference of colour to the surrounding integument. The hilum varies much in size, being sometimes very minute, while in other cases it extends for some distance over the surface of the integuments, as in the Horsechestnut and Calabar Bean. The hilum, as in the ovule, indicates the base of the seed, while the apex is represented by the chalaza. This chalaza (*fig.* 529, *ch*) is generally more evident in the seed than in the ovule, and is frequently of a different colour. It is well seen in the Orange, and commonly in anatropous and amphitropous seeds, in which case also the raphe may be generally noticed forming a projection on the surface of the seed.

FIG. 529.

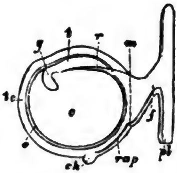


Fig. 529. The seed of a Pea, with its integuments removed on one side. *pl.* Placenta. *f.* Funiculus. *rap.* Raphe. *ch.* Chalaza. *m.* Micropyle. *te.* Testa or episperm. *e.* Endopleura. The part within the endopleura is the nucleus of the seed, and is formed of cotyledons *c*, gemmule or plumule *g*, radicle *r*, and *t* stalk or tigellum between the plumule and radicle.

The micropyle also, although smaller and less distinct than in the ovule, owing to a contraction of the surrounding parts, may be frequently observed on the seed (*fig.* 529, *m*). It should be noticed that while the micropyle constitutes the organic apex of the ovule, the chalaza indicates that of the seed.

The terms orthotropous, campylotropous, anatropous, and amphitropous are applied to seeds in the same sense as to ovules; consequently the hilum, chalaza, and micropyle have the same relations to one another in the seed as in the ovule.

In describing the position of the seed the same terms are used as already mentioned (page 304) under the head of the Ovule. The number of seeds is also indicated by corresponding terms as with ovules.

FIG. 530.

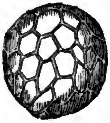


FIG. 531.

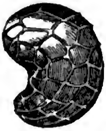


FIG. 532.

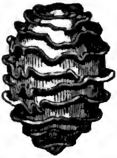


FIG. 533.

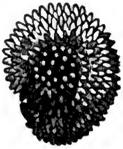


Fig. 530. Rounded seed of the Watercress (*Nasturtium officinale*). The testa is reticulated or netted.——*Fig.* 531. Reniform seed of the Poppy (*Papaver*), with an alveolate or pitted testa.——*Fig.* 532. Obovate seed of the Larkspur (*Delphinium*), the testa of which is marked with ridges and furrows.——*Fig.* 533. Seed of Chickweed (*Stellaria*), the testa of which is tuberculated.

Having now alluded to those characters, &c., which the seed possesses in common with the ovule, we pass to the consideration of its special characteristics.

Forms of Seeds.—Seeds vary much in form, and, in describing these variations, similar terms are employed to those used in like modifications of the other organs of the plant. Thus, a seed may be rounded, as in the *Nasturtium* (*fig.* 530); ovate, as in *Polygala* (*fig.* 538); oval, as in *Asclepias* (*fig.* 536); obovate, as in *Delphinium* (*fig.* 532); reniform, as in *Papaver* (*fig.* 531), &c., &c.

STRUCTURE OF THE SEED.—The seed consists essentially of two parts; namely, of a *Nucleus* or *Kernel* (*figs.* 31, *emb*, *alb*, and 537, N), and *Integuments* (*figs.* 31, *int*, and 537, T).

1. THE INTEGUMENTS OR COATS.—There are usually two coats to the seed. These have been variously named by botanists; the terms employed in this volume, and those most frequently in use, are *testa* or *episperm* for the outer coat, and *tegmen* or *endopleura* for the inner.

a. *Testa, Episperm, or Outer Coat* (*fig.* 529, *te*).—This integument may be either formed of the primine of the ovule only, or, as is more frequently the case, by the combined primine and secundine. The testa is generally composed of ordinary parenchymatous cells; but in some seeds, as in those of the *Acanthodium*, we have in addition a coating of hair-like cells containing spiral fibres.

In colour, the testa is more generally of a brown or somewhat similar hue, as in the Almond, but it frequently assumes other colours; thus, in some Poppies it is whitish, in others black; also it is somewhat black in the Pæony; in the Arnatto red; in the seeds of the Castor-oil Plant mottled; and various other tints may be observed in different seeds.

The testa also varies in texture, being either fleshy, or more or less spongy, or membranous, or coriaceous, or it assumes various other degrees of hardness, and thus becomes woody, crustaceous, &c.

The surface of the testa likewise presents various appearances, and is often furnished with different appendages. Thus it may be smooth; or wrinkled, as in *Nigella*; or striated, as in Tobacco; or marked with ridges and furrows (*fig.* 532); or netted (*fig.* 530); or pitted (*fig.* 531); or tuberculated (*fig.* 533); or spiny, as in the Mulberry. The testa of some seeds is also furnished with hairs, which may either cover the entire surface, as in various species of *Gossypium*, where they constitute the material of so much value called Cotton; or they may be confined to certain points of the surface, as in the *Asclepias* (*fig.* 536), and *Epilobium* (*fig.* 540). In the latter case the tufts of hairs thus confined to certain points of the testa constitute what is called a *coma*, and the seed is described as *comose.*

Other seeds, again, have winged appendages of various kinds; thus, in the Sandwort (*fig.* 535), the testa is prolonged, so as to form a flattened margin to the seed, which is then described as *marginate* or *bordered*; while in the seeds of the *Pinus* (*fig.* 534, *w*), the testa forms wings, and the seed is said to be *winged.*

FIG. 534.

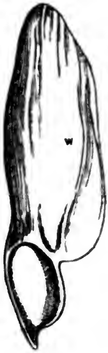


FIG. 535.

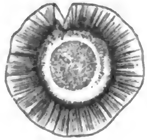


FIG. 536.

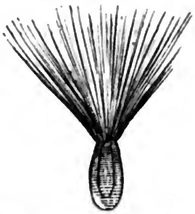


Fig. 534. Seed of a species of *Pinus*, with a winged appendage, *w*.——*Fig.* 535. Marginate or bordered seed of Sandwort (*Arenaria*).——*Fig.* 536. Comose oval seed of *Asclepias.*

The testa is also usually marked externally by a scar indicating the hilum or point by which it is attached to the funiculus or placenta. The micropyle, may be also sometimes seen on the surface of the testa, as in the Pea (*fig.* 529, *m*); and in anatropous and amphitropous seeds the position of the raphe is commonly indicated by a more or less projecting ridge on the surface; and where it terminates it forms the chalaza. But the latter can only be seen by removing the testa (*fig.* 529, *ch*).

b. *Tegmen, Endopleura, or Inner Coat* (*fig.* 529, *e*).—The inner coat of the seed is essentially parenchymatous like the outer. This integument may be either formed from the cells of the nucleus left surrounding (page 305) the embryo-sac, as is usually the case; or of the latter combined with the sac itself; or, in some instances, it appears to arise from the secundine of the ovule. Sometimes the embryo-sac in the ripe seed remains distinct from the albumen of the nucleus (*fig.* 541), and remains in the form of a sac which envelops the embryo, as in the Nymphæaceæ, Piperaceæ, and Zingiberaceæ; to this the name of *vitellus* has been given.

The endopleura is generally of a soft and delicate nature, although sometimes it is of a fleshy character either entirely or in part. It is usually of a whitish colour, and more or less transparent. This layer is closely applied to the nucleus of the seed, which it accompanies in all its foldings and windings; and in some cases even dips down into the albumen of the nucleus, and thus divides it more or less completely into a number of parts, as in the Nutmeg and Betel-nut (*fig.* 542, *p*). (*See* ALBUMEN.)

FIG. 537.

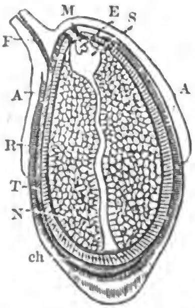


Fig. 537. Young anatropous seed of the White Water-Lily (*Nymphæa alba*) cut vertically. F. Funiculus. A, A. Arillus. T. Integuments. N. Nucleus. R. Raphe. *ch.* Chalaza. M. Micropyle. S. Embryo-sac. E. Rudimentary embryo.

Aril or Arillus.—Besides the two integuments described above as those that are found in all seeds, we occasionally find on the surface of seeds an additional integument, of which no trace is visible in the ovule. This is generally of a partial nature (*fig.* 537, A, A), and to it the name of *arillus* or *aril* has been given. Two kinds of aril have also been distinguished and called respectively the *true aril* and the *false aril* or *arillode.* These have an entirely different origin; thus, the *true aril* arises in a somewhat similar manner to the coats of the ovule already described (page 306), that is to say, it makes its first appearance around the hilum in the form of an annular process derived from the placenta or funiculus, and gradually proceeds upwards, so as to produce a more or less complete additional covering to the seed, on the outside of the testa. This arillus is well seen in the *Nymphæa* (*fig.* 537, A, A). But the *false aril* or *arillode* arises from the micropyle, and seems to be a development or expansion of the exostome, which gradually extends itself over the testa, to which it forms a covering, and after thus coating the seed it may be even bent back again so as to enclose the micropyle. This is well seen in the seed of the Nutmeg plant, where it forms a scarlet covering to the testa, and which is known in commerce, when dried and preserved, under the name of *mace.* In descriptive botany both the true aril and arillode are commonly designated under the general term of aril.

FIG. 538.

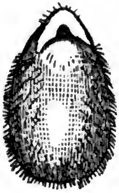


FIG. 539.

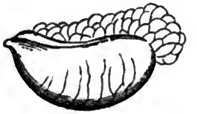


FIG. 540.

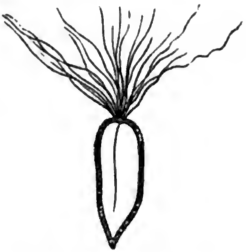


Fig. 538. Ovate seed of Milkwort (*Polygala*), with a caruncule at its base or hilum.——*Fig.* 539. Seed of Asarabacca (*Asarum*), with a caruncule on the side; this is called by some a raphian arillus.——*Fig.* 540. Section of the comose seed of *Epilobium*; the tuft of hairs is sometimes called a chalazal arillus.

Caruncule or Strophiole.—This is a small irregular protuberance found on various parts of the testa; and always developed, like the aril and arillode, subsequent to fertilisation. In the Milkwort (*fig.* 538) a caruncule is situated at the base or hilum of the seed; in the Asarabacca (*fig.* 539) on the side; while in the Spurge it is placed at the exostome.

2. THE NUCLEUS OR KERNEL (*figs.* 31, *emb*, *alb*, and 537, N).—The nucleus of the seed corresponds to the same portion of the ovule in a mature condition. In order to understand its structure, we must briefly narrate the changes which the nucleus of the ovule undergoes after the process of fertilisation has been effected. We have already stated that at an early period before impregnation has taken place, a quantity of protoplasmic matter of a semi-fluid nature is present in the embryo-sac. Very soon after fertilisation has been accomplished, frequently even before any change is apparent in the germinal vesicle, a number of cells are produced in the layer of protoplasm lining the embryo-sac. These cells, which contain nutritive matters of various kinds, especially designed for the nourishment of the embryo which is subsequently developed in the sac, are usually termed *endosperm cells.* The cells existing outside the embryo-sac also sometimes become filled with starch and other nutritive material, forming what has been called the *perisperm.* But as a general rule the endosperm is far more commonly found.

The embryo, in the course of its development by absorbing the nourishment by which it is surrounded, begins to enlarge, and in so doing presses upon the parenchymatous cells by which it is enclosed, and thus causes their absorption to a greater or less extent, according to the size to which it ultimately attains. In some cases the embryo continues to develop until it ultimately produces the destruction, not only of the parenchymatous tissue within the embryo-sac, as well as the sac itself, but also of that of the nucleus, and it then fills the whole interior of the seed, and is coated directly by the integuments. But at other times the embryo does not develop to any such degree; in which case it is separated from the integuments by a mass of parenchymatous tissue of varying thickness which may be derived from that of the nucleus itself, or from both that of the nucleus and embryo-sac according to the extent to which the embryo has developed. To the tissue which in such seeds thus remains and forms a solid mass round the embryo, the name of the *albumen* has been commonly applied; but as the nature of this substance is different from that called by chemists vegetable albumen, it is now often designated as the *perisperm* or *endosperm* according to its origin as described above. Both *endosperm* and *perisperm* may be seen in the seeds of *Nymphæa* (*fig.* 541), and *Piper*. As the general term albumen is the best understood in this country, we shall in future alone commonly employ it in this volume, and so long as we recollect its origin and nature, its adoption can lead to no confusion.

FIG. 541.

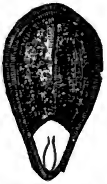


Fig. 541. Vertical section of the ripe seed of the White Water Lily, showing the embryo imbedded in albumen (*endosperm*), and enclosed in the remains of the embryo-sac or vitellus, and on the outside of this the albumen (*perisperm*), surrounded by the integuments.

From the above considerations it will be evident that the nucleus of the seed may either consist of the embryo alone, as in the Bean and Pea (*fig.* 529); or of the embryo enclosed in *albumen*, as in the *Nymphæa* (*fig.* 541), and Poppy (*fig.* 31, *alb*). We have two parts, therefore, to describe as constituents of the nucleus, namely, the albumen and the embryo.

a. *Albumen, Endosperm, and Perisperm.*—Those seeds which have the embryo surrounded by albumen, that is, by either endosperm or perisperm, or both, are said to be *albuminous*; while those in which it is absent are *exalbuminous*.

The cells of the albumen contain various substances, such as starch, aleurone grains, oily matters, &c., and thus act as reservoirs of nutriment for the use of the embryo during the process of germination. These varying contents of the cells, together with certain differences in the consistence of their walls, cause the albumen to assume different appearances in ripe seeds, and thus frequently to afford good characteristic or distinctive marks of different seeds. Thus, the albumen is described as *mealy*, *starchy*, or *farinaceous*, when its cells are filled with starch-granules, as in the Cereal grains; it is said to be *fleshy*, as in the Heartsease, when its walls are soft and thick; or when its cells contain oil-globules, as in the Poppy, it is *oily*; or when the cells are soft, and chiefly formed of mucilage, as in the Mallow, it is *mucilaginous*; or when the cells are thickened by layers of a hardened nature, so that they become of a horny consistence, as in the seeds of the Coffee plant, the albumen is described as *horny*. These different kinds of albumen are frequently more or less modified in different seeds by the admixture of one with the other.

FIG. 542.

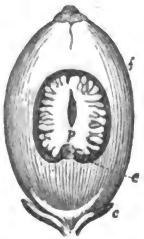


Fig. 542. Vertical section of the fruit of the Betel-nut Palm (*Areca Catechu*). *c.* Remains of perianth. *f.* Pericarp. *p.* Ruminated albumen of the seed. *e.* Embryo.

Generally speaking, the albumen presents a uniform appearance throughout; but at other times it is more or less separated into distinct compartments by the folding inwards of the endopleura as already described (see page 314). In the latter case the albumen is said to be *ruminated*, as in the Nutmeg and Betel-nut (*fig.* 542, *p*).

b. *The Embryo* is the rudimentary plant, and is therefore necessarily present in all true seeds, of which it is the most important part. It contains within itself, in a rudimentary state, all the essential parts of which a plant is ultimately composed. Thus we distinguish, as already noticed in our first chapter (page 13), three parts in the embryo; namely, a *radicle*, *plumule*, and one or more *cotyledons*. These parts may be readily recognised in many seeds; thus in the embryo of the Pea (*fig.* 12), the two fleshy lobes *c*, *c*, are the *cotyledons*, between which there is situated a little axis, *t* (*tigellum*), the upper part or bud-like portion of which is the *plumule*, *n*, and the lower part, *r*, the *radicle*. The *tigellum*, or *hypocotyledonary axis*, is generally a mere point, but at other times it forms a short stalk (*fig.* 14, *t*). Plants which thus possess two cotyledons in their embryo are called *Dicotyledonous*. But there are plants in which, as already noticed, there is commonly but one cotyledon present (*fig.* 544, *c*), and which are accordingly termed *Monocotyledonous*. In rare instances, however, a monocotyledonous embryo has more than one cotyledon, and then the second cotyledon alternates with the first, instead of being opposite to it, as is invariably the case with the two cotyledons of Dicotyledonous plants. By the difference thus presented in the embryos of Flowering Plants, they are divided, as already noticed, into the two great classes of *Dicotyledones* and *Monocotyledones*.

(a) *The Monocotyledonous Embryo.*—The parts of a monocotyledonous embryo are, in general, by no means so apparent as those of the Dicotyledones. Thus the embryo at first sight externally usually appears to be a solid undivided body of a cylindrical or somewhat club-shaped form, as in *Triglochin* (*fig.* 543); but if this be more carefully examined, a little slit or chink, *f*, will be observed on one side near the base; and if a vertical section be made parallel to this slit, a small conical projection will be noticed, which corresponds to the plumule; and now, by making a horizontal section, the cotyledon will be observed to be folded round the plumule, which it had thus almost entirely removed from view, only leaving a little slit corresponding to the union of the margins of the cotyledon; and which slit thus became an external indication of the presence of the plumule.

In other monocotyledonous embryos the different parts are more manifest; thus, in many Grasses, as, for instance, the Oat (*fig.* 498), the cotyledon, *c*, only partially encloses the plumule, *g*, and radicle, *r*; and thus these parts may be readily observed in a hollow space on its surface.

FIG. 543.

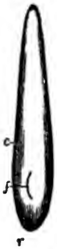


FIG. 544.

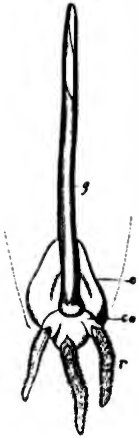


Fig. 543. Embryo of *Triglochin.* *r.* Radicle. *f.* Slit corresponding to the plumule. *c.* Cotyledon. From Jussieu.——*Fig.* 544. Germinating embryo of the Oat. *r.* Rootlets coming through sheaths, *co.* *c.* Cotyledon. *g.* Young stem.

The inferior extremity of the radicle is usually rounded (*fig.* 543, *r*), and it is through this point that the roots, *r*, burst in germination (*fig.* 544; see page 124). The radicle is usually much shorter than the cotyledon, and generally thicker and denser in its nature; but in some embryos it is as long, or even longer, in which case the embryo is called *macropodous.*

(b) *The Dicotyledonous Embryo.*—These embryos vary very much in form; most frequently they are more or less oval, as in the Bean and Almond (*fig.* 545), where the embryo consists of two nearly equal cotyledons, *c*, between which is enclosed a small axis or *tigellum*, *t*, the upper part of which, *g*, is the *plumule*, and the lower, *r*, the *radicle.* The tigellum upon germination appears as a little stalk (*fig.* 14, *t*), supporting the cotyledons.

In by far the majority of cases the two cotyledons are nearly of equal size, as in the Pea (*fig.* 12, *c*, *c*); but in some embryos, as in some *Hiræas* (*fig.* 546, *c′*, *c*), they are very unequal. Again, while the cotyledons usually form the greater part of the embryo (*fig.* 12, *c*, *c*), in other instances, as in *Pekea butyrosa* (*fig.* 547, *c*) they form but a small portion. Again, the cotyledons are sometimes altogether absent, as in *Cuscuta*; while at other times their number is increased, and this may either occur as an irregular character, or as a regular condition, as in many Coniferæ

FIG. 545.

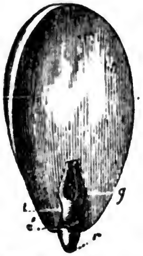


FIG. 546.

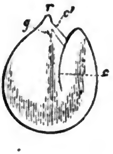


FIG. 547.

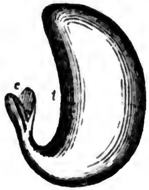


Fig. 545. The embryo of the Almond (*Amygdalus communis*) from which one of the cotyledons has been removed. *c.* The cotyledon which has been left. *r.* Radicle. *g.* Plumule. *t.* Tigellum. *c′.* Scar left by the removal of the other cotyledon.——*Fig.* 546. Vertical section of the embryo of a species of *Hiræa.* *c′.* Large cotyledon. *c.* Small cotyledon. *g.* Plumule. *r.* Radicle.——*Fig.* 547. The embryo of *Pekea butyrosa.* *t.* Large tigellum. *c.* Rudimentary cotyledons.

(*fig.* 549, *c*), where we frequently find six, nine, or even fifteen cotyledons; hence such embryos have been termed *polycotyledonous*. It is more probable, however, that this appearance of a larger number of cotyledons than is usual in Dicotyledonous plants, arises from the normal number becoming divided down to their base into segments. In all cases where the number of cotyledons is thus increased, they are arranged in a whorl (*fig.* 549, *c*).

FIG. 548.

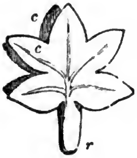


FIG. 549.

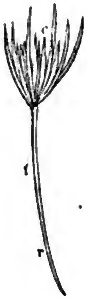


FIG. 550.

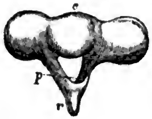


Fig. 548. Embryo of the Lime-tree (*Tilia europæa*). *c, c.* Cotyledons, each with five lobes arranged in a palmate manner. *r.* Radicle.——*Fig.* 549. The so-called polycotyledonous embryo of a species of *Pinus* beginning to germinate. *c.* Cotyledons. *r.* Radicle. *t.* Tigellum.——*Fig.* 550. The embryo of *Geranium molle*. *c.* Cotyledons, each of which is somewhat lobed, and furnished with a petiole, *p.* *r.* Radicle.

The cotyledons are usually thick and fleshy, as those of the Bean and Almond (*fig.* 545), in which case they are termed *fleshy*; at other times they are thin and leaf-like, as in the Lime (*fig.* 548, *c, c*), when they are said to be *foliaceous*.

The cotyledons are commonly sessile, and their margins are usually entire, but exceptions occur to both these characters; thus, in *Geranium molle* (*fig.* 550, *p*), they are petiolate; while in the Lime (*fig.* 548, *c*, *c*) they are distinctly lobed; and in the Geranium (*fig.* 550, *c*), they are also somewhat divided at their margins.

The cotyledons also vary in their relative positions to each other. Generally they are placed parallel, or face to face, as in the Almond (*fig.* 545), and Pea (*fig.* 12); but they frequently depart widely from such a relation, and assume others analogous to those already described in speaking of the vernation of leaves and the æstivation of the floral envelopes. Thus each of the cotyledons may be *reclinate*, *conduplicate*, *circinate*, *equitant*, or *obvolute*, &c.

FIG. 551.

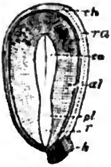


FIG. 552.

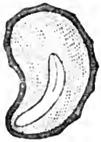


FIG. 553.

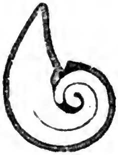


Fig. 551. Vertical section of the seed of the Pansy. *h*. Hilum. *pl*. Embryo with its radicle, *r*, and cotyledons, *co*. *ch*. Chalaza. *al*. Albumen. *ra*. Raphe. The embryo is erect or homotropous.——*Fig.* 552. Vertical section of the seed of the Poppy, with the embryo slightly curved in the axis of albumen.——*Fig.* 553. Vertical section of the seed of *Bunias*, showing its spiral embryo.

The position of the radicle in relation to the cotyledons is also liable to much variation. Thus the radicle may follow the same direction as the cotyledons, or a different one. In the former case, if the embryo be straight, the radicle will be more or less continuous in a straight line with the cotyledons (*fig.* 551, *r*); if, on the contrary, the embryo is curved, the radicle will be curved also (*fig.* 552), and sometimes the curvature is so great that a spiral is formed (*fig.* 553). In the latter case, where the direction of the cotyledons and radicle is different, the latter may form an acute, obtuse, or right angle to them; or be folded back to such an extent as to lie parallel to the cotyledons, in which case the radicle may be either applied to their margins (*fig.* 555, *r*), when the cotyledons are said to be *accumbent*; or against the back of one of them (*fig.* 554, *r*), when the cotyledons are *incumbent.*

We have now, in the last place, to allude briefly to the relation which the embryo itself bears to the other parts of the seed, and to the pericarp or cell in which it is placed.

Relation of the Embryo to the other Parts of the Seed, and to the Fruit.—In the first place with regard to the albumen. It must necessarily happen that when the albumen is present, the size of the embryo will be in the inverse proportion to it; thus in Grasses (*fig.* 498) we have a large deposit of albumen and but a small embryo, while in the Nettle (*fig.* 556) the embryo is large and the albumen very small. The embryo may be either external to the albumen (*fig.* 498), and thus in contact with the integuments, as in Grasses, in which case it is described as *external*; or it may be

FIG. 554.

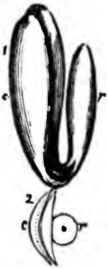


FIG. 555.

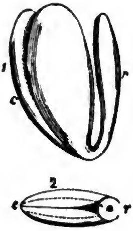


FIG. 556.

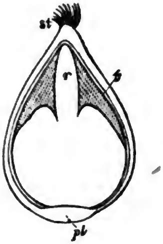


Fig. 554. Embryo of the Woad (*Isatis tinctoria*). 1. Undivided. 2. Horizontal section. *c.* Cotyledons. *r.* Radicle.——*Fig.* 555. Embryo of the Wallflower. 1. Undivided. 2. Horizontal section. *r.* Radicle. *c.* Cotyledons.——*Fig.* 556. Vertical section of the achænium of the Nettle, containing a single seed. *t.* Integuments of the seed. *pl.* Placenta. *r.* Radicle. *st.* Stigma.

surrounded by the albumen on all sides, except on its radicular extremity, as in the Pansy (*fig.* 551), when it is *internal.*

The embryo is said to be *axile* or *axial* when it has the same direction as the axis of the seed (*fig.* 551, *pl*); or when this condition is not complied with, it is *abaxile* or *eccentric* (*fig.* 557, *pl*). In the latter case, the embryo is frequently altogether on the outside of the albumen (*fig.* 558, *emb*), when it is described as *peripherical.*

As a general character the radicle is turned towards the micropyle (*fig.* 557, *r*), in which case it is said to be *homoblastic*, and the cotyledonary extremity to the chalaza, *ch*. Some apparent exceptions to these relative positions occur in the Euphorbiaceæ, and a few other plants, when the radicle is described as *enantioblastic*; but such are merely accidental deviations arising from certain trifling irregularities in the course of the development of the parts of the seed.

FIG. 557.

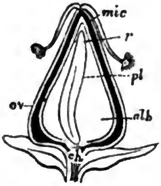


FIG. 558.

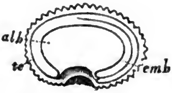


Fig. 557. Vertical section of the fruit and solitary erect orthotropous seed of the Dock (*Rumex*). *ov.* Pericarp. *mic.* Micropyle. *pl.* Embryo, which is inverted or antitropous, and turned towards one side of the albumen, *alb.* *ch.* Chalaza. *r.* Radicle.——*Fig.* 558. Vertical section of the seed of *Lychnis dioica.* *te.* Integuments. *emb.* Embryo on the outside of the albumen, *alb.* The embryo is amphitropous.

While the relation of the radicle and cotyledonous portion is thus seen to be generally constant, it must necessarily happen from the varying relation which the hilum bears to the micropyle and chalaza, that its relation to the radicle and cotyledonary portion of the embryo must also vary in like manner. Thus in an orthotropous seed (*fig.* 557), the chalaza and hilum coincide with each other, and the radicle is then turned towards the apex of the seed, and the cotyledonary portion to the chalaza and hilum; in this case the embryo is said to be *antitropous* or *inverted.* In an anatropous seed (*fig.* 551), where the micropyle is contiguous to the hilum, *h*, and the chalaza, *ch*, at the opposite extremity, the radicle, *r*, will point towards the hilum or base of the seed, and then the embryo is said to be *erect* or *homotropous.* In a campylotropous seed, where the chalaza and micropyle are both near to the hilum (*fig.* 558), the two extremities of the embryo, which in such cases is generally peripherical, become also approximated, and it is said to be *amphitropous.*

We have now lastly to explain the different terms which are in use to express the relations which the radicle of the embryo bears to the cavity or cell in which it is placed. We have already stated that the terms used in defining the position of the seed to the same cavity are employed in the same sense as previously mentioned when speaking of the ovule (page 305). But as regards the radicle, this is said to be *superior* or *ascending* (*figs.* 556, *r*, and 557, *r*), when it is directed towards the apex of the cell; *inferior* or *descending* when it points to the base; *centripetal* if turned inwards towards the axis or centre; and *centrifugal* when it is turned towards the sides.

Section 7. THEORETICAL STRUCTURE, OR GENERAL MORPHOLOGY OF THE FLOWER.

HAVING now taken a comprehensive view of the different organs of the flower, we are in a position to examine in detail the theory which has been kept constantly in view in their description, namely, that they are all modifications of one common type—*the leaf*; for it is now universally admitted that all the organs of the flower are formed upon the same plan as the leaf, or, in other words, that they are homologous parts, and that they owe their differences to special causes connected with the functions which they have severally to perform. Thus the leaf, being designed to elaborate nutriment for the support of the plant, has a form, structure, and colour which are adapted for that purpose; while the parts of the flower, being designed for the purpose of reproduction, have a structure and appearance which enable them to perform their several functions.

In the *first place*, it is evident that the *bract* is closely allied to the leaf, from its structure, figure, form, and colour, and from the ordinary development of one or more buds in its axil. But in order to be perfectly convinced of this analogy, let anyone examine the Foxglove or the Pæony, and then it will be seen that all stages of transition occur between leaves and bracts, so that it will be impossible to doubt their being homologous parts.

That the *sepals* are homologous with leaves is proved, not only by their colour and other characters, but also by the fact, that many flowers exhibit in a natural condition a gradual transition between sepals and bracts, and the latter, as already noticed, are readily referable to the leaf as the type. Thus, in the Camellia it is almost impossible to say where the bracts end and the sepals begin. In the Marsh Mallow (*fig.* 279) and Strawberry, again, the five sepals in the flowers of the two respectively alternate with five bracts: and the difficulty of distinguishing them is so great, that some botanists call both sets of organs by the name of sepals. In many flowers in a natural condition, therefore, there is a striking resemblance between sepals and leaves; and this analogy is at once proved to demonstration by the fact that in monstrous or abnormal flowers of the Rose, Clover, Primrose (*fig.* 559), and other plants, the sepals are frequently converted into true leaves.

We now pass to the *petals*, and although these in the majority of flowers are of a different colour to leaves and sepals, yet in their flattened character and general structure they are essentially the same; and their analogy to leaves is also proved in many natural flowers by the gradual transitions exhibited between them and the sepals. This is remarkably the case in the White Water-lily, where the flowers present several whorls of floral envelopes, which so resemble one another in their general appearance and colour, that it is next to impossible to say where the sepals end and the petals begin. In many other instances, also, there is no other way of distinguishing between the parts of the calyx and those of the corolla, than by their different positions,—the calyx being the outer series, the corolla the inner. The analogy between petals and leaves is still further shown by the fact, that the former are occasionally green, as in certain species of *Cobæa*, and also from their being occasionally converted, either entirely or partially, into leaves. We therefore conclude that petals, like sepals and bracts, are homologous with leaves.

FIG. 559.

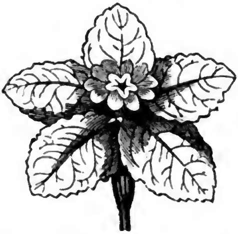


Fig. 559. Abnormal or monstrous Primrose flower, with the sepals converted into true leaves. From Lindley.

The *stamen* is, of all organs, the one which has the least resemblance to the leaf. If its structure, however, be carefully examined, the different parts of the leaf may be clearly recognised in those of the stamen; moreover, we find that in many plants the petals become gradually transformed into stamens. This is remarkably the case in the White Water-lily (*fig.* 375); thus in the flowers of this plant the inner series of petals gradually become narrower, and the upper extremity of each petal exhibits at first two little swellings, which, in those placed still more internal, become true anthers containing pollen. From the fact that the stamens can thus be shown to be merely modified petals, while the latter have been already proved to be modified leaves, it must necessarily follow that the stamens are so also. If we now refer to what takes place in many cultivated flowers we have conclusive evidence at once afforded to us of the leaf-like nature of stamens. Thus, in what are called double flowers, the number of petals is principally increased by the conversion of stamens into petals; hence the number of the latter increases as the former decreases. Thus, if a double Rose be examined, all sorts of transitions may be observed between true petals and stamens. In other cases the stamens have been actually transformed into true leaves. As far as the stamens, therefore, we have no difficulty in tracing, both in the normal and abnormal conditions of the parts of the flower, a regular and gradual transition from the ordinary leaves, thus forming conclusive evidence of their being formed upon a common type with them.

As regards the *carpel*, we find that transitional states between the stamen and carpel are unknown in the normal condition of flowers, the difference in the functions performed by them respectively being so opposite that it necessarily leads to corresponding differences in structure. We must, therefore, look to *monstrosities* or deviations from ordinary structure for examples of such conditions. Even these are by no means common. Such may, however, be occasionally found in the Houseleek, some Poppies, and in other plants. In a paper published by the author in the *Pharmaceutical Journal* for March, 1856, a very remarkable instance of this transition from stamens to carpels was described; it occurred in the *Papaver bracteatum*. Such examples clearly prove that the stamens and carpels are formed upon a common type, and hence that the latter are, like the former, homologous organs with leaves. The analogy of the carpel to the leaf is, however, constantly shown in cultivated flowers, even in a more striking manner than the stamen is thus proved to be a modified condition of that organ. Thus in many double flowers, as in Roses, the carpels, as well as the stamens, become transformed into petals. It is by no means rare, again, to find the carpels transformed into true leaves, as in the Double Cherry (*figs.* 415–417), as already fully described when speaking of the carpel. We have, therefore, as regards the carpel, the most conclusive evidence of its being formed upon a common type with the leaf, and that it is consequently homologous with it.

The carpel being thus shown to be homologous with the leaf, it must necessarily follow that the *fruit* is likewise a modified condition of the leaf, since it is formed of one or more carpels in a matured state.

Further proof of the homologous nature of the parts of the flower to the leaf is afforded by the fact that the floral axis, instead of producing flowers, will sometimes bear whorls of true leaves. In other cases the axis becomes prolonged beyond the flower, as in cultivated Roses (*fig.* 560), or beyond the fruit (*fig.* 561), and becomes a true branch bearing leaves. To this elongation of the axis the term *median prolification* is usually applied.

When a sepal becomes a petal, or a petal a stamen, or a stamen a carpel, the changes which take place are said to be owing to *ascending* or *direct metamorphosis*. But when a carpel becomes a stamen, or a stamen a petal, or petal a sepal, or if any of these organs become transformed into a leaf, this is called *retrograde* or *descending metamorphosis*.

We have thus proved by the most conclusive facts, that all the organs of the flower are formed upon a common type with the leaf, and differ only in their special development, or, in other words, that they are homologous parts. Hence a flower-bud is analogous to a leaf-bud, as we have already stated (page 176), and the flower itself to a branch the internodes of which are

FIG. 560.

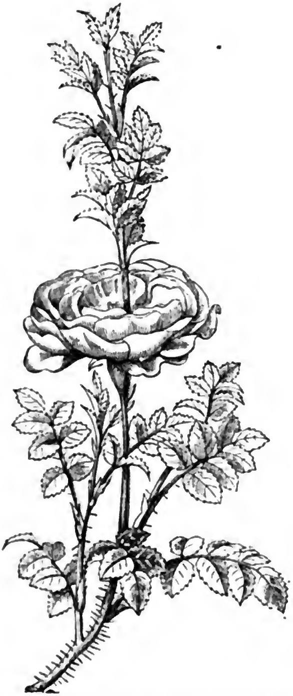


FIG. 561.

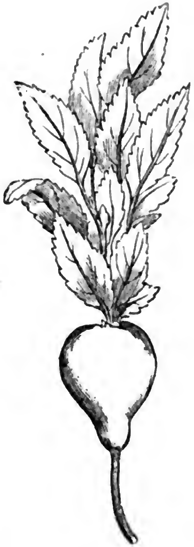


Fig. 560. Abnormal or monstrous development in the Rose, showing the axis prolonged beyond the flower and bearing true leaves.—— *Fig.* 561. A monstrous or abnormally developed Pear, showing the axis prolonged beyond the fruit, and bearing true leaves.

but slightly developed, so that all its parts are situated in nearly the same plane; and, as flower-buds are thus analogous to leaf-buds, their parts are also necessarily subject to similar laws of development and arrangement, and hence a knowledge of the latter gives the clue to that of the former.

CHAPTER V.

REPRODUCTIVE ORGANS OF CRYPTOGAMOUS, FLOWERLESS, OR ACOTYLEDONOUS PLANTS.

THE nutritive organs of Cryptogamous plants have been already briefly alluded to in the chapter on the General Morphology of the Plant, and in the sections treating of the stem, root, and leaf. But their reproductive organs have at present been only very generally referred to, hence we now proceed to describe them as fully as our space will allow.

The reproductive organs of the Cryptogamia differ widely from those of the Phanerogamia; for, in the first place, they have no flowers properly so called, and hence such plants are termed *Flowerless*. But although these plants have no flowers, and therefore no true stamens or carpels, they have organs which perform analogous functions to them and to which the names of Antheridia, Pistillidia, or Archegonia, and others, have been applied. As these organs are, however, more or less concealed or obscure, Flowerless plants have been also called Cryptogamous, which signifies, literally, concealed sexes. The term *asexual*, which was formerly applied to them, has now been proved to be generally incorrect.

Secondly, as Cryptogamous plants have no flowers, they do not produce true seeds or parts containing a rudimentary plant or embryo; but, instead of seeds, they form reproductive bodies called *spores*, which in most cases consist of one cell (or rarely, two or more), with commonly one or two coats, and enclosing granular and other matters. The term spore is, however, used in a very varied sense, as our sketch of the Reproductive Organs of the Cryptogamia will show. As used above, it is intended to apply to asexual reproductive cells. A spore, having no embryo, can have no cotyledonary body, which is an essential part of an embryo, consequently flowerless plants have been also called *Acotyledonous*. In germination, again, as the spores have no rudimentary stem or root, they have commonly no definite growth, but this takes place by an indifferent extension of one or both of their membranes. But some exceptions are afforded to this latter peculiarity by certain spores which have on their outer membrane certain spots or pores, through which, in germination, little threads are protruded from an extension of their inner membrane. The threads which are thus produced by the germination of spores may either reproduce the plant directly, or give rise to an intermediate body of varying form, called the *prothallium*, *prothallus*, or *pro-embryo* (*fig.* 566), from which the fructiferous or fruit-bearing frond or stem ultimately springs.

The Cryptogamous plants have been arranged, as already noticed (see page 11), in two great divisions, called Cormophytes and Thallophytes, under which heads we shall therefore give a sketch of the reproductive organs of the different natural orders which are comprised respectively within them.

Section 1. REPRODUCTIVE ORGANS OF CORMOPHYTES.

CORMOPHYTES, or, as they are also termed, Acrogens, have been divided into several sub-divisions or *Natural Orders*. Those commonly distinguished by botanists are, the *Filices*, *Equisetaceæ*, *Marsileaceæ*, *Lycopodiaceæ*, *Musci*, and the *Hepaticaceæ*.

1. FILICES OR FERNS.—The fructification of these

plants consists of little somewhat rounded cases, called *sporangia*, *capsules*, or *thecæ* (*fig.* 562, *sp*), springing commonly from the veins on the under surface or back of their leaves or fronds (*figs.* 562 and 563); or in some few instances, as in *Acrostichum*, from the upper surface; and containing spores in their interior. The sporangia are arranged in little heaps called *sori*, which vary much in form (*figs.* 562, *sp*, and 563, *s*); and are either naked, as in *Polypodium* (*fig.* 562), or covered by a thin membranous layer continuous with the epidermis, which is called the *indusium* or *involucre*, as in *Aspidium Filix-mas* (*fig.* 563). Sometimes the sporangia are so densely compacted that no intervening parenchyma can be distinguished—the latter being destroyed by the excessive development of the former; in which cases, instead of being collected in sori on the back of the fronds, they appear as little bodies

FIG. 562.

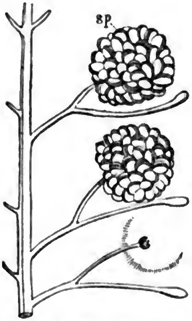


FIG. 563.

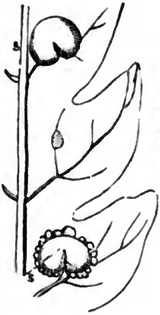


FIG. 564.

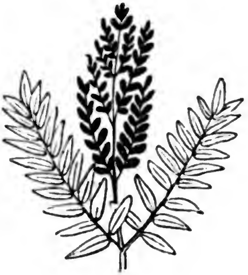


Fig. 562. A portion of the frond of the common Polypody (*Polypodium vulgare*), showing two sori springing from its veins. The sori are naked, and consist of a number of sporangia, *sp*, in which the spores are contained.——*Fig.* 563. Portion of the frond of the Male-fern (*Aspidium Filix-mas*), with two sori, *s*, *s*, covered by an indusium.——*Fig.* 564. Portion of the frond of the Royal or Flowering-fern (*Osmunda regalis*), with its sporangia arranged in a spiked manner on a branched rachis.

arranged in a spiked manner on a simple or branched rachis, as in *Osmunda* (*fig.* 564).

The *capsule* is a little cellular bag or case (*fig.* 565, *s*), usually stalked, *p*, and more or less completely surrounded by a ring or *annulus*; this ring is frequently elastic, and thus causes the bursting of the capsule when ripe, and the escape of its contained spores. In some Ferns the ring is imperfect, and in others it is altogether wanting: hence Ferns provided with a ring are called *annulate*, while those in which it is absent are said to be *exannulate*.

FIG. 565.

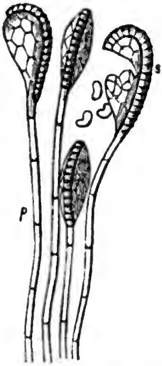


FIG. 566.

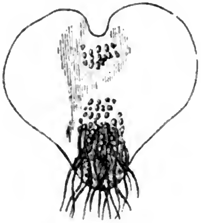


Fig. 565. Sporangia or capsules of a Fern. *s*. Sporangium supported on a stalk, *p*, and surrounded by a ring or annulus, which is a continuation of the stalk. One capsule is represented as burst on its side, and the contained spores in the act of being scattered.——*Fig.* 566. Under surface of the prothallium of a Fern, showing archegonia and antheridia with root hairs. After Berg and Schmidt.

The spores are usually somewhat angular in form, and have two coats like pollen-cells; and, like them, also, the outer coat, which has a yellowish or brownish colour, is either smooth or furnished with little points, streaks, ridges, or reticulations. In germination the inner coat is first protruded in the form of an elongated tube through an aperture in the outer coat, which ultimately bursts, and the tubular prolongation, by cell-division, forms a thin flat green parenchymatous expansion, called a *prothallium* (*fig.* 566), from which one or more radical fibres, or root-hairs, are commonly produced in its earliest stage. On the under surface of this body (*fig.* 566) there are soon produced two different structures, called *antheridia* and *archegonia*, which represent respectively the andrœcium and gynœcium of Flowering plants. The *antheridia* are cellular bodies (*fig.* 567) containing other minute cells called *sperm-cells*, *se*, in which are developed spiral ciliated filaments, *sp*, the antherozoids. The *archegonia* (*fig.* 568) are little cellular papillæ of a somewhat oval form, with a canal in their centre leading to a cavity which has been called the *embryo-sac*, and in which is a cell termed the *germ-cell* or *germ-corpuscle*. Impregnation takes place by the contact of the antherozoids with the germ-cell or germ-corpuscle, and from the development of this, after fertilisation, ultimately the plant with fronds bearing capsules is produced.

FIG. 567.

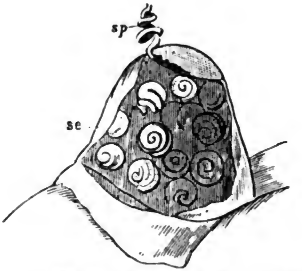


FIG. 568.

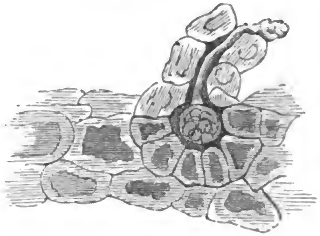


Fig. 567. Side view of an *antheridium* containing a number of *sperm-cells*, *se*. *sp*. Antherozoids escaping from the antheridium after having burst the sperm-cells.——*Fig.* 568. Vertical section of an archegonium, passing through the canal and embryo-sac. After Henfrey.

The Ferns are thus seen to exhibit in their growth two generations: in the first of which the spore produces a thalloid expansion, with antheridia and archegonia—the *prothallium* or *sexual generation*; and in the second, a new plant resembling the one from which the spore was originally derived—the *asexual generation* or *Fern proper*. Thus, Ferns exhibit an instance of what has been called *alternation of generaticns*.

2. Equisetaceæ or Horsetails.—In these plants the fully developed fructification, found usually in the early spring, is borne in cone-like or club-shaped masses at the termination of the stem-like branches (*fig.* 10). Each mass is composed of a number of peltate stalked scales, on the under surface of which numerous spore-cases, called *thecæ* or *capsules*, are arranged (*fig.* 569). These capsules, when ripe, open by a longitudinal fissure on their inner surface, and thus set free the contained spores.

Fig. 569.

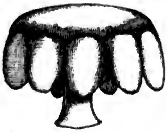


Fig. 570.

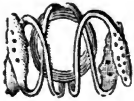


Fig. 571.

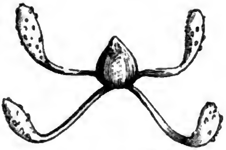


Fig. 569. Peltate stalked scale of a species of Horsetail (*Equisetum*), bearing on its lower surface a number of capsules or thecæ.——*Fig.* 570. Spore of a Horsetail furnished with two *elaters*, which are wound round it. The elaters are terminated at each end by a club-shaped expansion.——*Fig.* 571. The same spore in a dry state, showing the elaters in an uncoiled condition.

The spores present a very curious structure: they are little rounded or somewhat oval bodies, and are regarded by Henfrey as only possessing one true coat, in consequence of their outer coat splitting up in a spiral direction so as to form two elastic filaments which are attached by their middle to the spores, and terminated at each end by a club-shaped expansion (*figs.* 570 and 571). These spiral elastic filaments, which are called *elaters*, are at first wound round the spore (*fig.* 570), but when dry they ultimately uncoil (*fig.* 571), and thus appear to assist in the dehiscence of the capsule, and in the dispersion of the spore to which they are attached.

When these spores germinate, a little pouch-like process protrudes from their surface by an elongation of their membrane; this ultimately forms a green lobed flattened expansion, the prothallium, which differs however from that of the Ferns in usually being furnished only with antheridia or archegonia—the prothallia therefore are said to be diœcious, instead of monœcious as ordinarily in Ferns.

The male and female prothallia moreover differ somewhat in size, the former being the smaller of the two. As in Ferns also, from the germ-cell of the archegonium after impregnation by the antherozoids, a new plant is ultimately produced resembling in every respect that of the parent plant from which the spores were derived. As is the case in Ferns, therefore, we have in the Equisetaceæ also, an instance of *alternation of generations*.

3. MARSILEACEÆ OR PEPPERWORTS.—In the plants of this order the fructification is placed at the base of the leaf-stalks. It consists usually of a two-valved stalked *sporocarp* (*fig.* 572, *s*), which is generally many-celled, or sometimes only one-celled. The contents of the sporocarps, and the mode in which they are arranged, vary, however, in the different genera of this order, and hence it will be necessary for us to allude to them separately.

In *Marsilea*, the fructification consists of a stalked two-valved hardened sporocarp (*fig.* 572, *s*). The valves are held together by a mucilaginous ring, which is at first connected with the stalk of the sporocarp, but when the latter organ bursts, the ring becomes detached from the stalk at one end, straightens, and appears as a long mucilaginous cord, *p*, protruding from the sporocarp, and bearing on its sides somewhat oblong spikes of fructification, *f*. The spikes are at first enveloped in a membrane, and are composed of two distinct organs, called *antheridia*; and *pistillidia*, *macrosporangia*, or *sporangia*. These organs are attached to a sort of placenta, the antheridia being on one side, and the sporangia on the other.

Each *sporangium*, or female organ, contains but one spore called an *ovulary spore*, *macrospore*, or *megaspore*. It consists of a central nucleus, surrounded by a cellular coating except at its apex, where there is a little cavity.

FIG. 572.

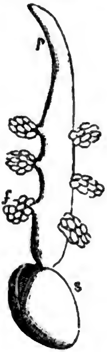


FIG. 573.

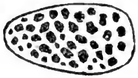


Fig. 572. Fructification of a species of *Marsilea*. *s*. Two-valved sporocarp. *p*. Peduncle. *f*. Fructification.——*Fig*. 573. Antheridium of the above, containing microspores.

According to Hofmeister, 'this cavity is gradually filled up with cellular tissue, constituting a conical prothallium confluent with the nucleus. A single archegonium is formed in the centre, the orifice of which corresponds with the apex of the prothallium.' In this an embryo is ultimately formed, which, when it germinates, gives off a frond in one direction, and a root in that opposite to it.

The *antheridia*, or male organs, contain a number of small cells (*fig*. 573), which ultimately develop long spiral spermatozoids; these small cells are called *pollen spores*, *small spores*, or *microspores* (*fig*. 644).

In *Pilularia* the fructification consists of stalked, pill-shaped, hairy sporocarps. The interior of each sporocarp is divided usually into four cells (*fig.* 574), and when ripe it opens by four valves. In the interior of each cell there is a mucilaginous process or placenta attached to the walls, upon which are placed numerous antheridia and sporangia, as in *Marsilea.* The structure of these antheridia and sporangia resembles in all essential particulars those of *Marsilea.* In fact, the only difference between the fructification of *Marsilea* and *Pilularia*, is the more complicated nature of the sporocarps in *Marsilea.*

FIG. 574.

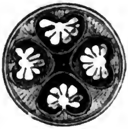


FIG. 575.

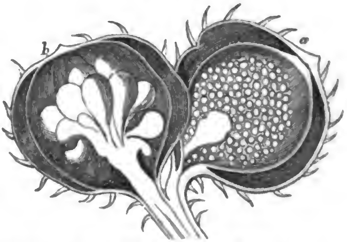


Fig. 574. Transverse section of the sporocarp or spore fruit of *Pilularia globulifera.* After Henfrey.——*Fig.* 575. Vertical section of the sporocarp of *Salvinia*, showing sporangia in one cavity, *b*, and antheridia in the other cavity, *a*.

The fructification of *Salvinia* (*fig.* 575) appears to resemble that of *Marsilea* and *Pilularia*, except that the antheridia, *a*, and sporangia, *b*, are here contained in separate sacs, and are attached to a sort of central cellular placenta. In germination, also, the prothallium of *Salvinia* differs from that of *Marsilea* and of *Pilularia*, in producing several archegonia, instead of only one, as is the case with them.

In reviewing the fructification of the Marsileaceæ, we find that it differs from the Filices and Equisetaceæ in producing two distinct kinds of spores, and in the prothallium not forming a distinct expansion on the outside of the spore, as is the case with them, but being confluent with the spore. These characters show that the Marsileaceæ are closely allied to the Lycopodiaceæ.

4. LYCOPODIACEÆ OR CLUB-MOSSES.—The fructification in the plants of this order is situated on the upper surface of their leaves at the base (*figs.* 576 and 577). The leaves thus bearing the fructification are frequently collected together into a kind of cone or spike, while at other times they are scattered along the stem. The spores, like those of the Marsileaceæ, are of two kinds, and are enclosed in separate cases. These cases are usually termed *sporangia* and *antheridia*; but the former are also called *macrosporangia* (*figs.* 576 and 579), and the latter *microsporangia* (*figs.* 577 and 578). The contents of the former are generally termed *large spores* or *macrospores* (*fig.* 579); those of the latter *small spores* or *microspores* (*fig.* 578).

FIG. 576.

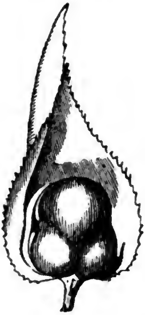


FIG. 577.

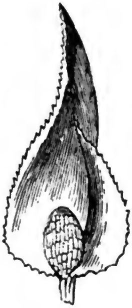
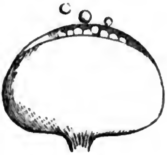


FIG. 578.



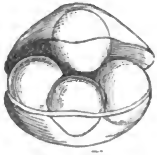


FIG. 579.

Fig. 576. Scale or leaf of *Selaginella apoda*, with macrosporangium in its axil.——*Fig.* 577. Antheridium or microsporangium of the above, placed in the axil of a leaf or scale. After Henfrey.——*Fig.* 578. Microsporangium of a species of *Selaginella*. It is two-valved, and contains a number of small spores or *microspores*.——*Fig.* 579. Macrosporangium of a species of *Selaginella*. This is a two-valved, four-lobed sac, and contains four large spores which are commonly called *macrospores*.

The *macrosporangia* are usually two-valved cases (*fig.* 579) with four lobes, each of which contains one large spore (*macrospore*). The macrospore is commonly only one-celled, but in some genera it is two-, three-, or many-celled.

The *antheridia* or *microsporangia* are somewhat reniform two-valved cases (*fig.* 578), containing a large number of small spores (*microspores*), in which antherozoids are ultimately produced (*fig.* 641).

In *Lycopodium* and some other Lycopodiaceæ, only one kind of spore-case has been found, which is of the nature of the antheridium or microsporangium.

The large spores are considered by Hofmeister and others as the analogues of the ovules. The antheridia or microsporangia are therefore to be considered as the male organs, and the macrosporangia as the female.

In germination, the large spore produces a prothallium in its interior (*fig.* 642), thus resembling the Marsileaceæ. In this archegonia (*fig.* 643, *a*) are soon developed, in which an embryo, and ultimately a new plant, is produced; fertilisation taking place by means of the antherozoids.

5. MUSCI OR MOSSES.—The reproductive organs of this order are of two kinds, which are called *antheridia* (*fig.* 580), and *archegonia* or *pistillidia* (*fig.* 581). These are surrounded by leaves, called *perichætial* (*fig.* 583, *f*), which are usually of a different form and arrangement to those of the stem; and in some Mosses they have, in addition to the perichætial leaves, another covering, formed of three or six small leaves of a very different appearance to them, termed *perigonial*, and constituting collectively a *perigone*.

The antheridia and archegonia sometimes occur in the same perigone, in which case such Mosses have been termed *hermaphrodite*. More frequently, however, they are in different perigones, and then both kinds of reproductive organs may occur on the same plant, or on separate plants; in the former case we apply the term *monœcious*, in the latter *diœcious*.

The *antheridium* or male organ is a somewhat elliptical, more or less rounded or elongated cellular sac (*fig.* 580, *a*), which is filled at maturity with a number of minute cells, *c*, termed *sperm-cells*; in each of these there is a single spiral *antherozoid.* The antheridium opens by an irregular perforation at its apex, and thus discharges the sperm-cells with their antherozoids. Among the antheridia there are generally to be found slender cellular jointed threads, *p*, called *paraphyses*, which are probably nothing more than abortive antheridia, as they appear to perform no special function.

FIG. 580.

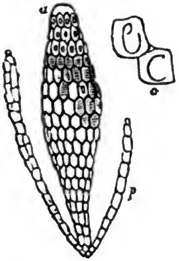


FIG. 581.

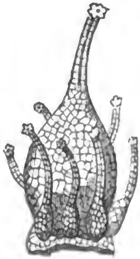


Fig. 580. Antheridium, *a*, of the Hair-Moss (*Polytrichum*), containing a number of cells, *c*, in each of which there is a single *antherozoid.* *p. Paraphyses*, surrounding the antheridium. —— *Fig.* 581. Archegonium or pistillidium of a moss surrounded by *paraphyses.*

The *archegonia*, like the antheridia, are also often surrounded by filamentous cellular bodies, called *paraphyses*, which appear to be in this case abortive archegonia (*fig.* 581). The *archegonium* or female organ is a flask-shaped cellular body with a long neck, the whole somewhat resembling an ovary with its style and stigma (*fig.* 581). The neck is perforated by a canal which leads into a cavity, at the bottom of which is a single cell, called the *germ* or *embryonal cell.* The case of the archegonium is called the *epigone.* This germ-cell appears to be fertilised, as in Ferns, by the antherozoids passing down the canal until they reach it. In the case of Mosses, however, the fertilised germ-cell does not directly develop a new plant like its parent, but after fertilisation has taken place the germ-cell becomes gradually developed into a somewhat conical or more or less oval body (*fig.* 582, *sp*) elevated on a stalk, *t*, and as it grows upwards it bursts the epigone, and carries one portion of it upwards as a kind of hood (*fig.* 583, *c*), while the other portion remains below as a sort of sheath (*fig.* 582, *v*), round the stalk. The central portion formed by the development of the embryonal cell is called the *sporangium* (*figs.* 583, *u*, and 584, *u*); the stalk the *seta* (*figs.* 583, *p*, and 584, *s*); the hood the *calyptra* (*figs.* 583, *c*, and 584, *c*), and the sheath at the base the *vaginule* (*fig.* 582, *v*). It will thus be seen that what is commonly called the fructification of Mosses—namely, the sporangium—is not the real fructification, but its product.

FIG. 582.

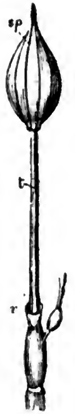


FIG. 583.

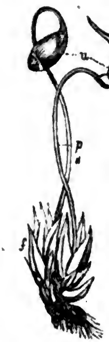


FIG. 584.

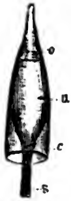


FIG. 585.

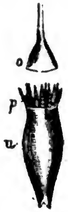


Fig. 582. ***Coscinodon pulvinatus.*** ***sp.*** Sporangium enclosed in the *calyptra*. *t*. *Seta* or stalk. *v*. Vaginule. From Henfrey.——*Fig.* 583. The Hygrometric Cord-moss (*Funaria hygrometrica*). *f*. Perichætial leaves. *p*. Stalks or *setæ*, each of which supports a sporangium, *u*, covered by a calyptra, *c*.——*Fig.* 584. Sporangium of the Extinguisher-moss (*Encalypta vulgaris*) before dehiscence. *u*. Sporangium covered by a transparent calyptra, *c*, and supported on a seta, *s*. Beneath the calyptra is seen the lid or operculum, *o*.——*Fig.* 585. The sporangium, *u*, of 584 after dehiscence. The calyptra and operculum, *o*, being removed, the *peristome*, *p*, may be seen.

The *sporangium*, or *capsule* as it is also termed, when fully formed, is a hollow urn-like case (*figs.*

586 and 587, *u*), the centre of which is usually occupied by a cellular axis, called the *columella* (*fig.* 588), and the space between this axis and the walls of the sporangium is filled with free spores, which are small cells with two coats and markings resembling those of pollen-cells. The sporangium is either indehiscent; or it opens by four vertical slits so as to form four valves, as in the sub-order *Andrœeœ*; or more commonly by a transverse slit close to its apex, like fruits with circumscissile dehiscence, by which a kind of lid is produced, called the *operculum* (*figs.* 585, *o*, and 586), which is either persistent or deciduous.

FIG. 586.

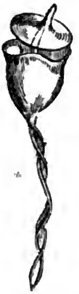


FIG. 587.

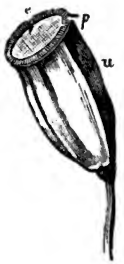


FIG. 588.

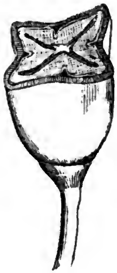


Fig. 586. ***Pottia truncata***, showing the separation of the operculum from the sporangium, From Henfrey.——*Fig.* 587. Sporangium, *u*, of the Hair-moss deprived of its calyptra and operculum. *p*. Peristome. *e*. *Epiphragma* or *tympanum*.——*Fig.* 588. Transverse section of a sporangium of the Hair-moss, showing the columella surrounded by free spores.

The wall of the sporangium is commonly described as consisting of three cellular layers, the outer of which forms the *operculum* just described, and the inner two layers the *peristome*. At the dehiscence of the sporangium the *stoma* or *mouth* is entire, smooth, or unfurnished with any processes (*fig.* 586); or it is surrounded by one or two fringes of teeth, called collectively the *peristome* (*fig.* 585, *p*), which, as just stated, are formed from the two inner layers of the wall of the sporangium. These teeth are always four or some multiple of that number. Sometimes a membrane from the inner wall is stretched across the mouth of the sporangium, and forms what has been called the *epiphragma* or *tympanum* (*fig.* 587, *e*). When the mouth is naked, the Mosses in which such a sporangium is found are called *gymnostomous* or *naked-mouthed*; when the mouth is surrounded by a single row of teeth, they are said to be *aploperistomous*; or, when with two rows, they are *diploperistomous*. The different appearances presented by the teeth, as well as their number and degree of cohesion, form important distinctive characters in the different genera of Mosses. The operculum, as already stated, is formed by a projection of the outer layer of the wall of the sporangium. At the point where the operculum separates an elastic ring or *annulus* is produced, which encircles the mouth of the sporangium.

In germination, the inner coat of the spore is protruded as a tubular process, which, as it elongates by cell-division, forms a green cellular branched mass, or *prothallium*, like a *Conferva*, called the *protonema* (*fig.* 640), upon the threads of which are subsequently delevoped leafy stems, and bearing ultimately archegonia and antheridia. In Mosses we have, therefore, another instance of alternation of generations.

6. HEPATICACEÆ OR LIVERWORTS.—The reproductive organs of Liverworts are of two kinds like those of Mosses, to which this order is closely allied; they are called *antheridia*, and *archegonia* or *pistillidia*, and both kinds may be found on the same plant, or on different plants; hence these plants are either *monœcious* or *diœcious*.

The *antheridia* or male organs are variously situated in the different genera of this order; thus, in the leafy plants they are placed in the axil of leaves, as in some species of *Jungermannia*; in other plants they occur in the substance of the frond or thalloid expansion, as in

Riccia; and in others, as in *Marchantia*, they are found imbedded in the upper surface of peltate or discoid-stalked receptacles (*fig.* 589, *r*). The *antheridia* are small, generally shortly stalked, cellular sacs, of an oval (*fig.* 590), or somewhat flask-shaped form, in which are contained a number of small sperm-cells; and their walls are usually formed of a double layer of cells. When ripe the antheridium bursts and discharges its contents; the sperm-cells also burst, and each emits a single *antherozoid*, in the form of a spiral thread with two or three coils, somewhat like those of *Chara*.

FIG. 589.

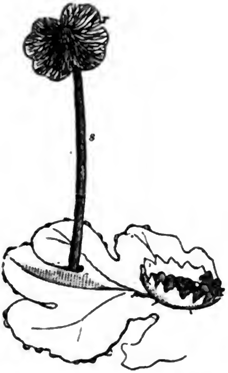


FIG. 590.

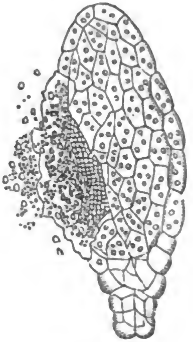


Fig. 589. A portion of the thallus or thalloid stem of *Marchantia polymorpha*. *r*. Receptacle, supported on a stalk, *s*. In the upper surface of the receptacle the antheridia are imbedded.——*Fig.* 590. Antheridium of *Marchantia*, discharging its small cellular contents (*sperm-cells*).

The *archegonia* or female organs, like the antheridia, are differently arranged in different genera; thus, in *Riccia* they are imbedded in the substance of the frond, while in *Marchantia* (*fig.* 591) they are buried in the under surface of the receptacles, *r*, which are elevated above the thallus on stalks, *s*. They are usually small flask-shaped bodies, each of which consists of a cellular case or *epigone* (*fig.* 592), having a canal in its upper elongated portion which leads to a cavity, at the bottom of which a single free cell, called the *germ* or *embryonal cell*, is developed. The germ-cell is doubtless fertilised, as in Ferns and Mosses, by the passage of the antherozoids down the canal until they come in contact with it. The fully developed archegonia, like those of Mosses, have also at times an additional covering surrounding the epigone, called the *perigone*, which frequently grows up so as to form a sort of cup-shaped covering (*fig.* 592, *b*). At the base of the perigone, a number of cellular filaments, perichætial leaves, or paraphyses, are also occasionally to be found, *c*, *c*.

FIG. 591.

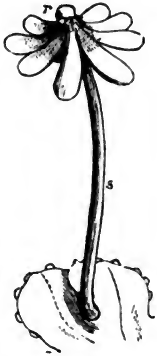


FIG. 592.

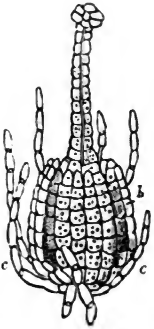


Fig. 591. A portion of the thallus or thalloid stem of *Marchantia polymorpha*. *r*. Receptacle supported on a stalk, *s*. On the under surface of the receptacle the archegonia and sporangia are imbedded.——*Fig.* 592. Archegonium of *Marchantia*. *b*. *Perigone*, open at its apex, and surrounding an inner cellular case or *epigone*. *c*, *c*. *Paraphyses*.

As in the case of Mosses, the fertilised germ-cell does not directly develop a new plant like its parent, but after fertilisation the germ-cell enlarges and bursts through the epigone, and forms a *sporangium* or *capsule*;

the epigone either remaining as a sort of sheath round the base of the sporangium, which is called the *vaginule*, or its upper part is carried upwards as a sort of hood or styloid *calyptra*.

The sporangia vary much in different genera. In *Marchantia* they are formed of two layers of cells; one external, called the *cortical* or *peripheral* layer, and the other internal, in which the spores, &c., are developed. The cells of the cortical layer exhibit spiral fibres, like the cells constituting the inner lining of the anther in Flowering plants. The cells forming the internal layer are thus described by Henfrey:—'At an early period the cells of the internal mass present the appearance of a large number of filaments radiating from the centre of the sporangium to the wall. These soon become free from each other, and it may then be perceived that some are of very slender diameter, and others three or four times as thick. The slender ones are developed at once into the long *elaters* (*fig.* 593, *e*) characteristic of this genus, containing a double spiral fibre, the two fibres, however, coalescing into one at the ends. The thicker filaments become subdivided by cross partitions, and break up into squarish free cells, which are the parent cells of the spores, four of which are produced in each.'

FIG. 593.

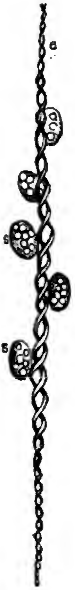


Fig. 593. Elaters, *e*, of *Marchantia*. *s*, *s*. Spores.

The sporangia in this genus are situated on the under side of the receptacle, and vary in form;—they burst by valves. In *Jungermannia* (*fig.* 7) the sporangia are elevated upon stalks arising out of a vaginule; they are more or less oval in form, and open by four valves which spread in a cross-like form; they contain spore-cells and *elaters* with a single spiral filament. In *Anthoceros* the sporangia open by two valves, and have a central axis or *columella*; they are of an elongated, tubular, or conical form, and are situated on a short stalk, and contain spore-cells and elaters, but the latter have no spiral fibres in their interior, and are much simpler in their structure than those just described as found in *Marchantia*. In *Riccia* the sporangia are imbedded in the substance of the frond, and have neither elaters nor columella. They have no regular dehiscence.

The spores have usually two coats, like pollen-cells; and the outer coat also frequently presents markings of different kinds; but in *Marchantia* (*fig.* 503, *s*, *s*) the spores have but one coat. They mostly germinate without any intermediate prothallium, although some produce a kind of prothallium in the form of a confervoid mass, or *protonema*, like a Moss (see page 347).

Section 2. REPRODUCTIVE ORGANS OF THALLOPHYTES.

THE Thallophytes may be divided into four large natural groups or orders, called respectively, Fungi, Lichens, Characeæ, and Algæ, in each of which again several subordinate divisions have been made.

1. FUNGI OR MUSHROOMS.—To give a detailed description of the various organs of reproduction occurring in the different sub-divisions of this order would be beyond the scope of this volume, and we will therefore simply choose a few examples as types of the different methods by which reproduction may take place. For this purpose we adopt the classification proposed by De Bary, according to which the Fungi are divided into the following groups, viz.:—(i) Phycomycetes, (ii) Hypodermiæ, (iii) Basidiomycetes, and (iv) Ascomycetes.

(i) *Phycomycetes.*—As an example of this group we will briefly describe the life history of *Cystopus candidus*, a fungus which is commonly found growing upon Cruciferous plants. On examining a plant infested by *Cystopus*, it will be seen that the greatly elongated one-celled mycelium of the fungus is interwoven, as it were, among its cells, and draws nourishment from it by means of little rounded projections, known as *haustoria*. After vegetating for some time in this manner, erect branches grow out from the surface of the epidermis, from which conidia—that is, reproductive cells which are produced asexually—are formed by a process of budding. From these conidia, when moistened with dew, rain, &c., zoospores are formed,

FIG. 594.

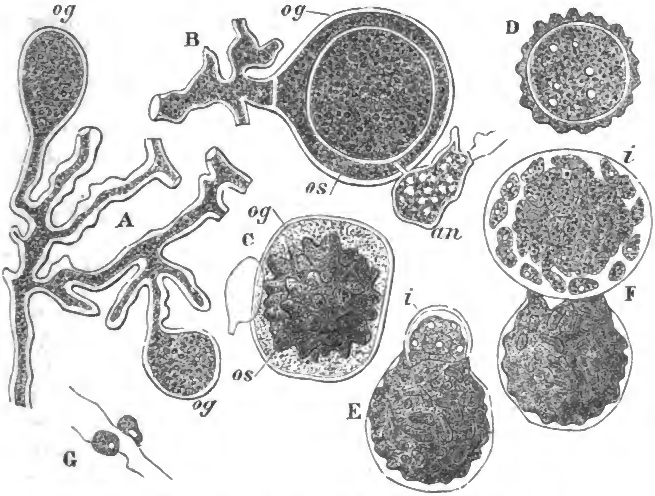


Fig. 594. A. Mycelium of *Cystopus* with young oogonia, *og*, *og*. B. Portion of mycelium bearing oogonium, *og*, with the oosphere, *os*; and antheridium, *an*. C. Mature oogonium, with *os*, the oospore. D. Mature oospore. E, F. Formation of swarmspores or zoospores, G, from oospores. *i*, *i*. Protruded endospores. After De Bary.

and these settling down upon a similar plant will, under favourable circumstances, again develop the *Cystopus* mycelium.

But *Cystopus* can also produce zoospores by means of a sexual process, which takes place in the interior of its host. The ends of certain filaments of the mycelium swell up, forming *oogonia* (*fig.* 594, A, *og*, *og*); whilst two club-shaped bodies, the *antheridia*, are formed by branches which arise from near the base of the oogonium. In the course of its development, the *oogonium* becomes of a more or less spherical form (*fig.* 594, ,B *og*), and at its base a septum is formed separating it from the general cavity of the *Cystopus* mycelium, whilst the greater part of the protoplasm contained in the oogonium arranges itself so as to form a rounded mass known as the *oosphere*, *os*.

When fertilisation is about to take place, one or other of the antheridia comes in contact with the oogonium (*fig.* 594, B, *an*),—and subsequently the protoplasm of the antheridium reaches that of the oogonium by penetrating the membrane of the latter. An *oospore* is thus formed (*fig* 594, C, *os*), which becomes surrounded by a rough dark brown coat or *exospore* (*fig.* 594, D), and ultimately by an inner coat or *endospore*. After lying dormant during the winter, the protoplasm of the oospore becomes divided into numerous segments (*fig.* 594, E, F), from each of which is formed a *zoospore* or *swarm-spore*. The endospore ultimately forces itself like a bladder (*fig.* 594, E *i*, F *i*) through the exospore, and then bursting, the zoospores, G, are set free, each of which, like those from the conidia, may settle down and produce a new *Cystopus* mycelium.

(ii) *Hypodermiæ.*—*Puccinia graminis*, which we will take as the type of this group, is remarkable not only in showing a distinct alternation of generations; but also in the fact that each generation is developed upon a different host; and thus affording a good example of what has been called *heterœcism*, or changing from host to host during different stages of development.

Thus in the spring, the fungus (*fig.* 595) may be seen in one phase of its existence growing on the Barberry (*Berberis vulgaris*), whilst in the summer, upon certain Grasses, fungous growths (*fig.* 596) may be seen which have been developed from spores formed whilst the *Puccinia* was inhabiting the Barberry, and which in fact constitute the second generation.

FIG. 595.

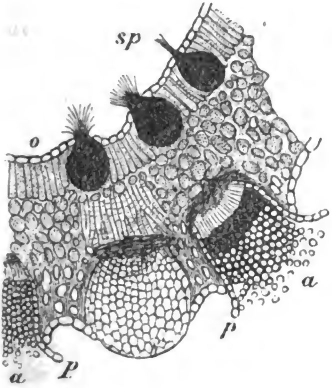


FIG. 596.

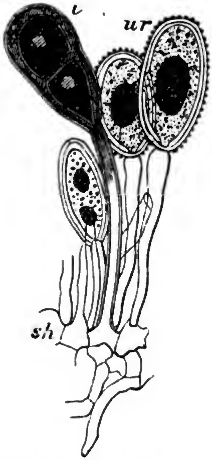


Fig. 595. Section through leaf of Barberry infested with *Puccinia graminis*. *o*. Epidermis of upper surface of leaf. *sp*. Spermogonia. *p*, *p*. Layers of cells (*peridium*), surrounding, *a*, *a*, the æcidium fruits. After Sachs.——*Fig*. 596. Part of a layer of uredospores. *sh*. Hyphæ or mycelium ramifying among the cells of a leaf of the Couch Grass. *ur*. Uredospores. *t*. A teleutospore. After De Bary.

If a section be made through one of the yellowish swellings seen on the leaf of a Barberry plant which is affected by the fungus, the whole tissue of the leaf at the spot in question will be found to be permeated by the mycelium of the *Puccinia*, whilst two kinds of fructification may be noticed, one on either side of the leaf. On the upper surface (*fig.* 595, *o*) are somewhat rounded spaces, termed *spermogonia*, *sp*, full of very delicate hair-like bodies, and from the floor of the cavity very small spore-like structures, the *spermatia*, are formed. On the under surface are the much larger *æcidium fruits* or *æcidia*, *a*, *a*. These consist of closely-packed vertical hyphæ from which, by a process of continuous budding, a great number of conidia-like spores are detached. It is by the germination of these spores and their growth on Grasses, that what are known as the *uredo-fruits* are produced.

These fruits consist of a dense mycelium (*fig.* 596, *sh*), interwoven among the cells of the Grass leaf, from which vertical branches shoot upwards bearing at their extremities oval granular spores, the *uredospores*, *ur*. These uredospores, germinating in other Grasses, again produce uredo-fruits, and this process may be carried on throughout the summer. But towards autumn some of the older uredo-fruits produce what are known as the *teleutospores* (*fig.* 596, *t*). These are two-celled, somewhat elongated spores, which, germinating upon the Barberry leaf, give rise to the æcidium fruits which we have already described.

It will be noticed that as yet no sexual process has been discovered to occur during the life history of *Puccinia*. Should such be hereafter demonstrated, it will probably be found that the æcidia are formed in consequence of the fertilisation of female organs by the spermatia.

(iii) *Basidiomycetes.*—As an example of this group we will briefly describe what is known of the life history of the common Mushroom (*Agaricus campestris*). That which is ordinarily known as the Mushroom is in reality the *receptacle*, *fructification*, or *spore-producing structure*, growing from a mycelium (*fig.* 597, *my*), which is vegetating underneath the surface of the ground or other substance upon which the fungus may be growing. The *receptacle*, in the case which we are considering, consists of two parts, viz.—the *cap* or *pileus*, *p*, and the *stalk* or *stipe*, *st*. The former may be regarded as the essential part of the receptacle, the spores being produced on its under surface, whilst the stalk simply serves the purpose of raising the pileus some distance above the ground.

FIG. 597.

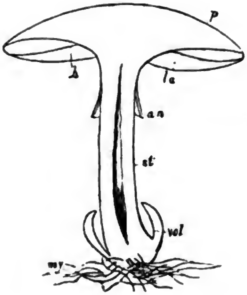


FIG. 598.

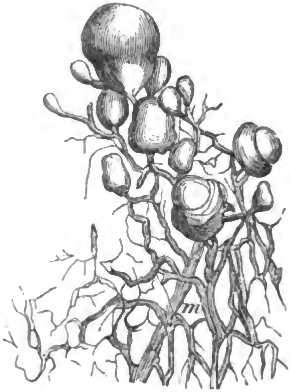


Fig. 597. Vertical section of the common Mushroom (*Agaricus campestris*). *my.* Mycelium. *vol.* Remains of volva. *st.* Stipe. *an.* Annulus. *h.* Hymenium with its gills or lamellæ, *la.* *p.* The pileus.——*Fig.* 598. *m.* Mycelium of *Agaricus*, bearing numerous young receptacles in different stages of development. After Sachs.

In the earlier stages of development the young receptacle consists of small, solid, somewhat pear-shaped bodies (*fig.* 598), made up of a dense mass of hyphal tissue continuous with that of the mycelium, *m*. As growth proceeds in these bodies, an annular air cavity is formed near the upper part, the roof of which forms the under side of the pileus, and, growing rapidly in a transverse direction, ultimately becomes covered by a number of closely set vertical folds placed in a radiating direction from the centre to the margin: these are the lamellæ or gills, and collectively constitute the hymenium (*fig.* 597, *la*), upon which the spores are produced in a manner to be presently described. The growth of the cap gradually causes the floor of the cavity, known as the *veil* or *indusium*, to give way from the margin, so that it comes at last to hang from the stalk in the form of a fringe or *annulus* (*fig.* 597, *an*).

In some species of Agaricus, as the present, the whole plant is entirely enclosed at first in a kind of veil or covering, called the *volva*, which ultimately becomes ruptured, and free from the tissue forming the membrane on the upper surface of the pileus; but its remains may be seen at the base of the stalk (*fig.* 597, *vol*).

If a transverse section of one of the lamellæ of a mature hymenium be made, it will be seen to consist of cells, greatly elongated in the centre, constituting the *trama* (*fig.* 599, *t*), but being smaller and more or less rounded towards the periphery, where they form what is known as the *sub-hymenial layer*, *sh*. Placed upon and derived from this layer are the densely crowded club-shaped cells known respectively as the *basidia*, s', s'', s''', s'''', or *paraphyses*, *q*, according as they produce spores or remain sterile.

From each basidium, in this species, two spores are produced, the process of their development being as follows:—On the free rounded surface of the basidial cell there first appear two little processes (*fig.* 599, s'), which quickly become swollen at their extremities, s''. The swelling in each instance increases, and finally a protoplasmic cell is produced, s''', which ultimately becomes separated from the little stalk, s'''', and forms a spore. The spores, thus formed, when placed under favourable circumstances, are capable of producing the mycelium, or dense network of hyphæ, from which again the fructification or receptacle is developed. Judging from analogy, we should have expected the fructification to be the result of a sexual process taking place in the mycelium, thus giving rise to an alternation of generations, but from the latest researches on the subject this does not seem to be the case.

FIG. 599.

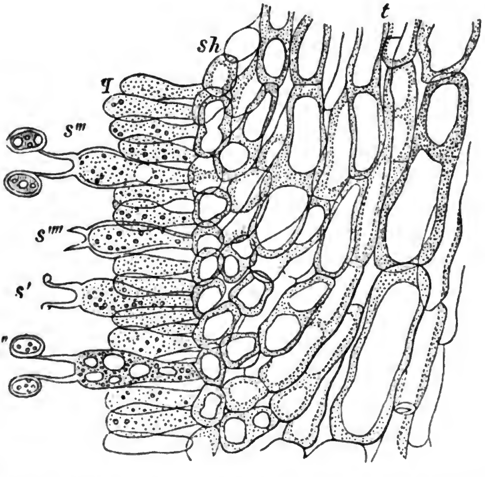


Fig. 599. Transverse section of a lamella of the mature hymenium of *Agaricus campestris*. *t*. Trama. *sh*. Sub-hymenial layer. *g*. Paraphyses. s', s'', s'''. Basidia in different stages of development, showing formation of spores. s''''. Basidium after the spores have fallen off. After Sachs.

(iv) *Ascomycetes.*—From this division of Fungi two examples may be selected for description.

The first which we will consider is *Claviceps purpurea*, or the Ergot Fungus. If we trace the development of this Fungus upon the ovary of the affected Grass (Rye being the one more commonly selected), we find that it first produces what is known as the *sphacelia* (*fig.* 601). On examining a section of an ovary in this condition, it is seen to be almost completely surrounded by a dense mass of hyphal tissue, which also penetrates more or less into its interior, and gradually, in fact almost entirely, takes the place of the proper structure of the ovary—this being more particularly the case towards the base of the organ.

From the free ends of the outer hyphæ great numbers of conidia (*fig.* 601) are produced by budding, which appear to have the power of again producing sphacelia in other Grasses. Finally, the hyphal tissue becomes much more dense, this taking place gradually from the base to the apex, until the *sclerotium* (*fig.* 600, *c*) or *Ergot*, which is ultimately (*fig.* 602) a somewhat horn-shaped body of a dark purple colour, is formed.

FIG. 600.

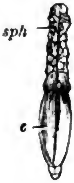


FIG. 601.

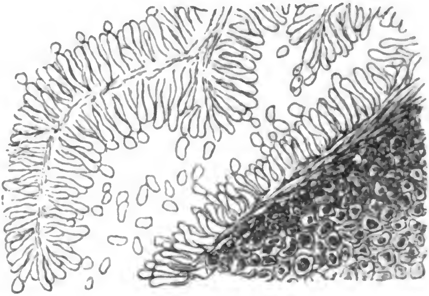


Fig. 600. Young sclerotium, *c*, of *Claviceps* growing up and supplanting the old sphacelia, *sph*.——*Fig.* 601. Section through the junction of the sphacelia with the sclerotium of *Claviceps*, showing formation of conidia.

After remaining dormant during the winter, the *Ergot* or *Sclerotium* produces spores in the following manner. Stalked receptacles (*fig.* 602) grow up from the tissue of the Ergot, in which are developed a number of *perithecia* (*fig.* 603). These *perithecia* are somewhat flask-shaped cavities (*fig.* 604), which are filled with

FIG. 602.

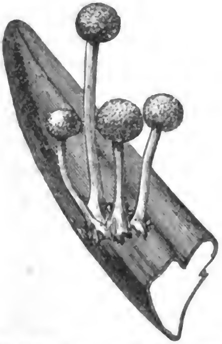


FIG. 603.

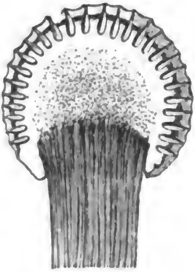


Fig. 602. Portion of the horn-shaped sclerotium of *Claviceps purpurea*, or the Ergot Fungus, bearing four stalked receptacles.——*Fig.* 603. Longitudinal section of a receptacle of the same, magnified, showing the perithecia. After Tulasne.

FIG. 604.

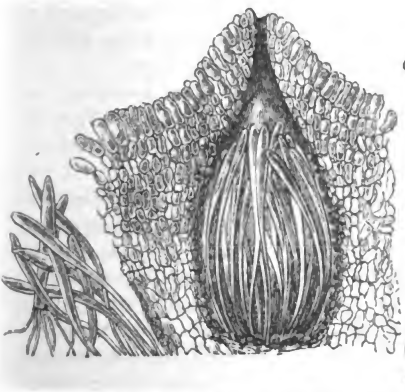


FIG. 605.

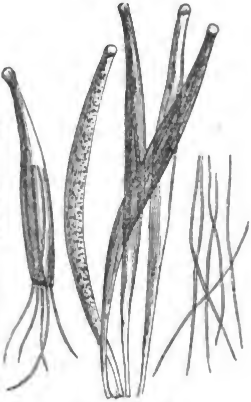


Fig. 604. A single perithecium of *Claviceps purpurea*, magnified, showing the contained asci.——*Fig.* 605. Asci of the same, containing the long slender ascospores. After Tulasne.

asci (*fig.* 605); the latter containing long slender spores, termed *ascospores*, which again, by germinating on the Rye or allied Grasses, can again give rise to the sphacelia.

Peziza, our second example of the Ascomycetes, is a genus of Fungi containing a great number of species, many of which are very common, and may be seen growing upon the dead trunks of trees, &c. *Peziza* is recognised as a small disc-shaped body, slightly cupped on the upper surface and of a reddish-purple colour. On close examination it is found that this structure (which is in fact the fructification) is growing from, and continuous with, a mycelium vegetating under the surface of the wood, &c., upon which the Fungus is situated. On examining a vertical section under the microscope it is seen to consist of numbers of elongated cells closely packed side by side. Of these the greater number are very narrow and somewhat club-shaped at the extremities; whilst the others are broader (*fig.* 606, *a–f*) and each contains eight oval spores in a greater or less state of development. The latter, *a–f*, are known as the *asci*, and their contained spores, which are produced by free cell-formation, are termed *ascospores*; whilst the former very narrow elongated cells are sterile branchlets, which are known as the *paraphyses*.

That which we have been describing, however, is only one phase of the life-history of *Peziza*, as this is one of the Fungi in which a clearly marked alternation of generations exists.

At a certain period of the year there appear on the *Peziza* mycelium branches directed vertically upwards, which, after branching and rebranching, produce structures by means of which a sexual process takes place. These consist of *antheridia* (*fig.* 607, *i*), and what may be termed *oogonia*, *a*; the latter being ovoid vesicles placed at the extremities of the branchlets, whilst the former is an elongated club-shaped body rising from below the base of the oogonium. The antheridium, *i*, finally unites with the oogonium, *a*, through the interposition of a hook-shaped process, *f*, on the latter, and as a result of the fertilisation a number of hyphæ, *h*, *h*, shoot up from the base of the oogonium, and which ultimately develop so as to form the fructification which we have already examined (*fig.* 606).

FIG. 606.

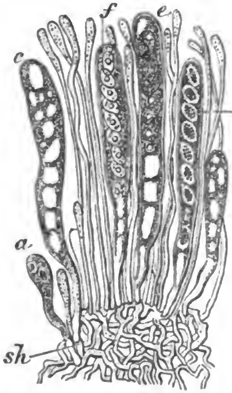


FIG. 607.

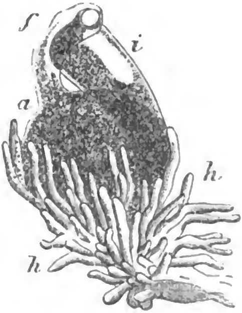


Fig. 606. *sh.* Sub-hymenial layer of the mycelium or hyphæ of *Peziza convexula.* *a*, *b*, *c*, *d*, *e*, *f*. Successive stages of development of the asci and ascospores intermixed with slender paraphyses. After Sachs.——*Fig.* 607. *h*, *h*. Mycelium or hyphæ of *Peziza confluens.* *a*. Oogonium with hooked process, *f*. *i*. Antheridium. After Tulasne.

2. LICHENES OR LICHENS.—From the more recent researches which have been made on this order of plants, it appears to be most probable that Lichens are in reality Ascomycetous Fungi, parasitic upon Algæ. As however this question cannot as yet be considered as absolutely settled, and as moreover Lichens present so many characteristics peculiar to themselves, we have thought it well to describe them and their modes of reproduction, under a separate head. According to the view then that Lichens are species of Fungi, the chlorophyll-containing cells or *gonidia* (*figs.* 610, *gon*, and 612, *gon*),

found within the substance of their thallus, and which used formerly to be regarded as special asexual reproductive organs, are in reality Algæ upon which the Fungus is parasitic. Thus the thallus of a Lichen is a compound structure, consisting of two elements, the *fungal* and the *algal*.

The reproductive organs of Lichens are of three kinds:—(1) Apothecia; (2) Spermogonia; and (3) Pycnidia.

The *apothecia* are of various forms, and have received different names accordingly; the more usual are the round (*fig.* 609, *ap*), and linear (*fig.* 608); the latter are commonly termed *lirellæ*. The apothecia may be either sessile or stalked; the stalk, when present, is termed the *podetium*. The apothecium is either composed of two parts, called the *thalamium* and *excipulum*, or, of the former only; when the latter is found, it forms a partial or entire covering to the thalamium. The body of the apothecium constitutes the *thalamium*, and the layer of cells at the bottom of this, upon which the thecæ and paraphyses are placed, is termed the *hypothecium*. When the apothecium is divided by a

FIG. 608.

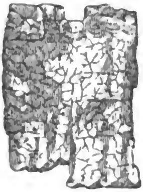


FIG. 609.

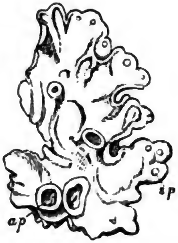


Fig. 608. Thallus of *Opegragha atra*, showing linear apothecia, termed lirellæ.——*Fig.* 609. Portion of the thallus of *Parmelia parietina*, with young round *apothecia*, *ap*, and *spermogonia*, *sp*. After Henfrey.

vertical section, it is seen to contain a number of spore-cases called *asci* (*fig.* 610, *as*), surrounded by thread-like or somewhat club-shaped filaments, called *paraphyses*, *par*, which are usually regarded as abortive asci; the asci and the paraphyses are placed perpendicularly upon the hypothecium. The apothecia are frequently of a different colour from the surrounding thallus; this is due either to the paraphyses or the excipulum. Each of the asci, *as*, generally contains eight spores, but in some cases only four, and in others sixteen; thus the spores are commonly a multiple of two, and the number is always constant for each species. In rare cases the asci have a large number of spores, and are hence said to be polysporous. The spores themselves are usually termed *ascospores*. Some of these spores are of a very complex structure, being divided into two, four, or many cells. They are frequently highly coloured, and form beautiful objects under the microscope.

FIG. 610.

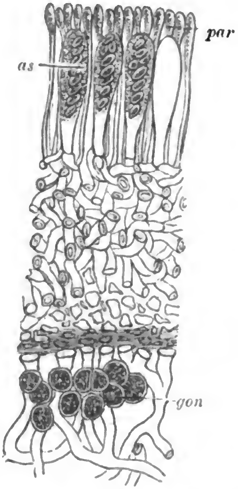


Fig. 610. Section of the thallus through an apothecium of *Cetraria islandica*. *as.* Asci, three of which contain ascospores. *par.* Paraphyses. *gon.* Gonidia. After Berg and Schmidt.

In a very few genera of Lichens, as *Abrothallus* and *Scutula*, certain structures have been discovered by Tulasne, called *stylospores*. 'They consist of isolated spores borne upon shortish simple stalks. They are produced in conceptacles to which is applied the name of *pycnidia*.'

The *spermogonia* were first discovered by Tulasne but they have been now found in a great number of Lichens, and probably exist in all. They generally appear as little black specks (*fig.* 609, *sp*), near the margins of the thallus, in the tissue of which they are usually more or less imbedded; but rarely, they are quite free and above the thallus. The spermogonium varies in form, and has one or more cavities, with a small orifice at the top termed the *ostiole* or *pore* (*fig.* 611, *os*), with which all the cavities communicate. The spermogonium, when mature, has its interior filled with a number of bodies called *spermatia* (*figs.* 611, *s*, and 612, *s*), raised on stalks, termed *sterigmata* or *spermatophores* (*figs.* 611, *sp*, and 612, *sp*). The form of the spermatophores varies much: according to Henfrey, 'The simplest are short slender stalks, simple or branched; or they are articulated branches composed of a great number of cylindroid or globular cells (*fig.*

FIG. 611.

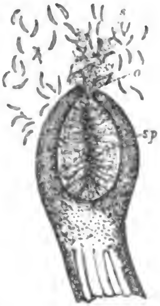


FIG. 612.

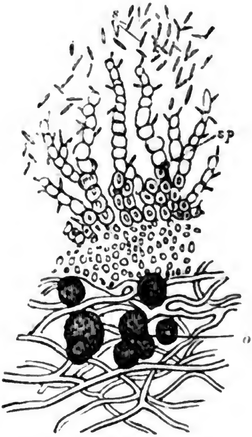


Fig 611. Vertical section of a spermogonium of *Cladonia rangiferina*. *sp*. Spermatophores. *os*. Ostiole or pore, from which the spermatia, *s*, are escaping.——*Fig*. 612. Highly magnified fragment from the wall of a spermogonium of *Parmelia parietina*. *sp*. Articulated sterigmata or spermatophores. *s*. Spermatia. *gon*. Gonidia. After Henfrey.

612, *sp*); or the branches are reduced to two or three elongated cells. The *spermatia*, *s*, are terminal on the spermatophores, and consist of exceedingly minute bodies, ordinarily linear, very thin, short or longish, straight or curved, without appendages, and motionless, and lie in a mucilage of extreme transparency. The spermatia are commonly regarded as the analogues of the spermatozoids produced in the antheridia of the higher Cryptogams.' When the spermogonium is mature, the spermatia (*fig.* 611, *s*), are discharged through the pore or ostiole, *os*, in vast numbers.

Lichens may also be produced in a vegetative manner by means of little detached portions of the thallus known as *soredia.* These are regarded by those who maintain the compound nature of Lichens as consisting of some of the Algæ, through which the Lichen derives its nutrition, connected and intermingled with a weft of fine fungal hyphæ. Such a soredium when placed under favourable conditions is capable of growing into a Lichen of the same nature as that from which it derived its origin.

3. CHARACEÆ OR CHARAS.—By many botanists the Charas are classed among the Algæ, but as they present in their structure and mode of reproduction many points of difference, we have placed them in a separate group immediately preceding the latter order.

The reproductive organs are of two kinds, both of which grow at the base of the branches, and either on the same or on different branches of the same plant, or on different plants. These organs are called, respectively, *globules* and *nucules.*

The *globule* (*fig.* 613, *a*), which is regarded as an antheridium or male organ, is a globular body, usually placed immediately below the nucule, *s*, but occasionally by its side. Of a green colour whilst young, it turns to a deep brick-red as it becomes mature. It consists of eight valves, or, as they have been termed, *shield-cells*, each of which is a flattened triangular or quadrangular cell, curved so as to present a convexity to the outer surface of the globule, and having its margins crenated or toothed, so as to dovetail as it were with the adjoining shield-cells. From the centre of each shield an oblong cell (*fig.* 615, *c*), the manubrium, is given off in a perpendicular direction. The eight cells from the eight shields converge in the centre of the globule. A ninth cell of a similar form, but larger than the others, also penetrates into the centre of the globule between the four lower shield-cells; this is the stalk which fixes the globule to the branch upon which it is placed. At the central end of each manubrium is a rounded cell, which supports in turn four other smaller cells, and from each of these latter four confervoid filaments are given off (*fig.* 615,

FIG. 613.

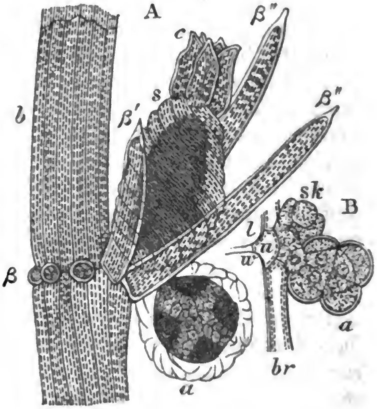


Fig. 613. A. Portion of the axis of *Chara fragilis*. *s*. Nucule or pistillidium. *a*. Globule or antheridium. *b*. Internode. *c*. Crown or corona of nucule. β. Nodal cells. β', β'', β''. Sterile leaflets. B. *sk*, nucule, and *a*, globule, both in an early stage of development. *w*. Nodal cell of leaf. *u*. Union cell between it and basal node of globule. *l*. Cavity of internode of leaf. *br*. Cells of leaf covered with cortex. After Sachs.

fil), in each cell of which is produced a single spiral *spermatozoid* or *antherozoid* (*fig.* 614), which is furnished with two very long ciliæ of excessive fineness. These spermatozoids ultimately escape from the cell by a sudden movement resembling the action of a spring, and may then be seen to exhibit active movements in water.

FIG. 614.

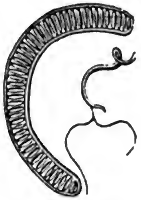


FIG. 615.

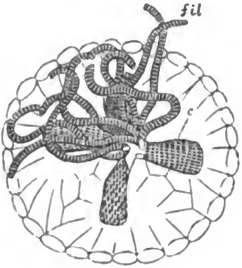


FIG. 616.

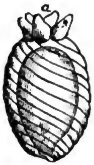


FIG. 617.

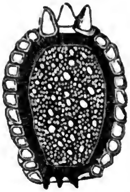


Fig. 614. A portion of a filament, *fil*, of *fig.* 615, with a ciliated *spermatozoid* or *antherozoid* by its side.——*Fig.* 615. A globule cut in half, to show the oblong cells or manubria, *c*, and the septate filaments, *fil*. After Henfrey.——*Fig.* 616. Nucule of *Nitella*. *a*. Apices of the spirally wound cells.——*Fig.* 617. Vertical section of a nucule.

The *nucule* is regarded as a pistillidium or archegonium. It is an oval sessile body, situated in the axil of a branch (*fig.* 613, *s*); it consists of a central cell containing protoplasm, oil, and starch granules (*fig.* 617), and surrounded by five cells, which are wound spirally round it, and terminating above in five or ten smaller cells, the ends of which remain free (*fig.* 616, *a*), and thus form a kind of crown at the apex of the nucule (*figs.* 613, A, *c*, and 616, *a*). At an early stage of growth the cells are separated from each other, and a canal is thus left between them extending from the crown towards the central cell. This canal is supposed to form a passage, by means of which the antherozoids reach the central cell of the nucule (*fig.* 617) by which it is fertilised. Ultimately the nucule drops off, and when it germinates, first produces a single axial row of cells, forming a pro-embryo, from which the leaf-bearing sexual plant ultimately grows (*fig.* 639).

FIG. 618.

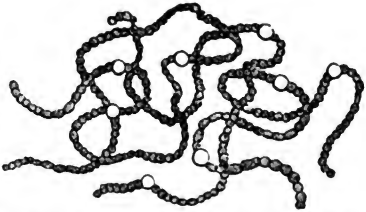


Fig. 618. Filaments from a *Nostoc* colony. After Luerssen.

4. ALGÆ OR SEAWEEDS.—This order of plants, like the Fungi, comprises a very large number of species, which vary exceedingly in form, size, colour, and other peculiarities. They are all either inhabitants of water, salt or fresh, or live on moist surfaces; and may be microscopic plants, or growths of enormous size. Adopting no special classification of the Algæ, we will simply describe the processes of reproduction occurring in certain examples as types of the rest.

Nostoc, a very common Alga, is found living sometimes in water, though more frequently on the damp surfaces of trees, stones, &c. It consists of a jelly-like substance, in which are imbedded moniliform threads of cells (*fig.* 618), the different filaments being interwoven with one another. The greater number of the constituent cells contain chlorophyll; but usually there are also placed at definite distances from one another larger colourless cells, which are not, like the others, capable of division, and are ordinarily known as the *heterocysts* (*fig.* 618). By means of the growth and subsequent division of the smaller cells, the *Nostoc* colony may become increased in size, and new colonies also at certain times become formed in the following manner. By means of the imbibition of water the jelly of the old colony swells up and allows the *Nostoc* filaments or rows of cells to become free. Each cell subsequently grows rapidly in a transverse direction till the appearance is presented by each filament of a number of disc-like bodies placed side by side. Cell-division next takes place in a direction parallel to the axis of the filament, so that a number of septate thread-like bodies are produced, which, joining by their ends, grow so as to ultimately produce a new *Nostoc* colony. At the same time the heterocysts are developed from cells which previously differed in no apparent respect from the rest, and the jelly-like envelope of the colony becomes also gradually formed.

Spirogyra, our next example of this order of plants, is one in which the process of reproduction known as conjugation very commonly takes place. *Spirogyra* is an Alga which may be found in great quantities in most ponds towards the end of summer, and is one of the prettiest objects which can be examined under the microscope. Seen with the naked eye, it consists of a mass of long, very slender, green threads or filaments, which float in the water where they are growing. Examined with the microscope, each filament is seen to be more or less cylindrical, and composed of a great number of similar cells placed end to end (*fig.* 619). The chlorophyll is arranged in the parietal layer of protoplasm of the cell in a definite spiral manner; the name of some of the species being determined by the number of such spirals in a single cell. Each cell is capable of growth and division, and by this means the bulk of the entire plant is increased.

When conjugation is about to take place, two filaments approach each other, and from the sides of contiguous cells (*fig.* 619, *a*, *b*, *c*), protrusions of the wall occur which meet in the centre. The walls then intervening between the cavities of the two conjugating cells next become absorbed (*fig.* 620, A, *a*), and the protoplasm of one cell separates itself from its cell-wall, and gradually travels into the other cell, where it becomes intimately mixed with the protoplasm existing there. The whole mass then becomes of a somewhat oval shape, surrounds itself with a cell-wall, and in fact constitutes what is called a *zygospore* (*figs.* 620, A, *b*, and B, *c*). Later on its colour changes from green to that

FIG. 619.

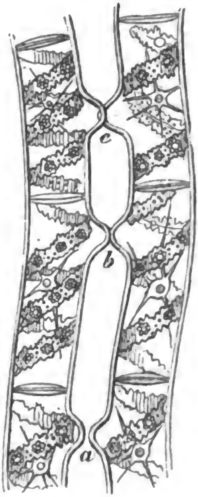


FIG. 620.

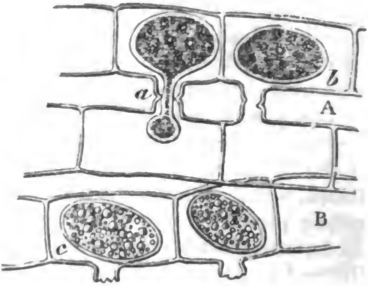


Fig. 619. Two filaments of *Spirogyra* about to conjugate; each cell is seen to contain chlorophyll arranged in spiral bands with grains of starch, oil globules, and a central nucleus, surrounded by protoplasmic threads which extend to the cell-wall. *a*, *b*, *c*. Lateral protrusions of the cell-walls of adjoining cells. ——*Fig.* 620. A. Filaments of *Spirogyra* conjugating. *a*. Formation of a zygospore. *b*. Formed zygospore. B. A filament in which are young zygospores, *c*, and which are seen to contain drops of oil. After Sachs.

of a deep red, and after remaining dormant during the winter the zygospore germinates at the beginning of spring, and so gives rise to a new *Spirogyra* plant.

Vaucheria, which we will now consider, exhibits true sexual reproduction, in addition to the formation of asexual spores. An irregular kind of alternation of generations exists in this genus, inasmuch as asexual spores are usually produced by a certain number of successive generations, the sexual process only taking place in generations separated by a considerable interval from one another. At the same time it must be noticed that asexual spores may be formed in the same plant as that in which sexual reproduction takes place. *Vaucheria* may be found growing either in water or on moist surfaces. Its thallus consists of one very elongated and greatly branched cell, attached to some fixed object by means of a portion of its thallus, which is much branched and perfectly transparent (*fig.* 621, D, *w*). The other, or non-transparent portion of the cell contains protoplasm, chlorophyll grains, and fre-

FIG. 621.

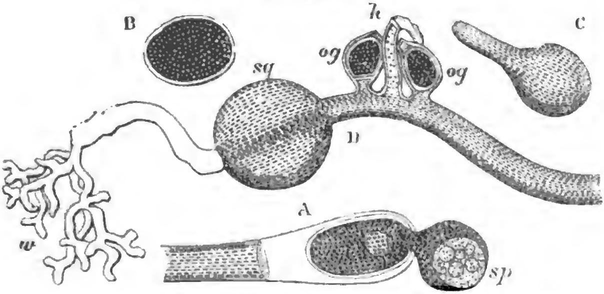


Fig. 621. A. *sp.* Newly formed zoospore or zoogonidium of *Vaucheria sessilis* escaping. B. Zoospore at rest after having lost its cilia. C. First stage of germination. D. Filament of *Vaucheria sessilis* producing oogonia, *og*, *og*, and antheridium, *h*. *w*. Hyaline root-like process, forming a sort of mycelium. *sp*. Zoospore. After Sachs.

quently numbers of small oil globules. The asexual spores are formed in various ways in the different species, the more common method being that in which a small branch becomes separated from the parent cell by division, the protoplasm thus shut off secreting a cell-wall round itself, and thus forming a spore, which ultimately germinating gives rise to a new *Vaucheria* thallus. (M. C. Cooke and Bates have recently described the main filaments or threads as much divided off by septa into cells at the period of fructification; and Cooke believes that from this circumstance and others that zoogonidia may be produced in *Vaucheria* in cells divided off for that purpose.)

Zoospores or *Zoogonidia* are also not unfrequently formed as follows:—The contents of the branch, which has swollen into a sporangium, contract, and escape as a primordial cell from a fissure at the apex (*fig.* 621, A, *sp*). This primordial cell is densely covered by short cilia, and is termed a *zoospore* or *zoogonidium*, which at first rapidly rotates; but it soon comes to rest, when the cilia disappear, and a cellulose wall is produced (*fig.* 621, B). This spore then germinates by putting out one (*fig.* 621, C) or two tubes, or it forms on the other side, at the same time, a branched root-like organ.

When sexual reproduction takes place, short branches of the thallus or filament, which are in close proximity to each other, become transformed into *antheridia*, *h*, and *oogonia*, *og*, *og* (*fig.* 621, D). The branch which is to form the antheridium is longer than the other which forms the oogonium, and generally becomes more or less curved, and a division is made about halfway from its base. The protoplasm in the upper part becomes differentiated into antherozoids, which by means of the bursting of the antheridium become free at the same time as the rupture of the oogonium takes place.

The *oogonia* (*fig.* 621, D, *og*, *og*), of which there are frequently two near to each other, are somewhat ovoid; they differ from the antheridia in containing a good deal of chlorophyll, and are separated from the cavity of the thallus by a septum situated at their base. The green and granular contents finally collect in the centre of the oogonium and colourless protoplasm is to be seen at its end; the cell-wall then opens at this point, and the contents at the same time retract from the cell-wall and what is termed the *oosphere* is formed. The antheridium opens at the same time as the oogonium, and the antherozoids escape, reach the oosphere, mix with it, and then disappear; and the oosphere is transformed into an *oospore*. The oospore thus formed acquires a distinct cell-wall of its own, and its colour also changes to a reddish hue. By the germination of the oospore, a new *Vaucheria* thallus may be formed.

Fucus.—This genus includes numerous species, which form the various plants commonly known as Seaweeds. The thallus (*fig.* 5) is usually long, very much branched, and of a greenish brown colour. In structure, it is made up at the surface of closely packed small cells, but towards the interior the cells are more elongated, and joined end to end, so as to form filaments which are interwoven amongst one another. The walls of the constituent cells are peculiar in consisting of two parts, an inner firm layer, and an outer one which is generally more or less swollen by imbibition of water.

Reproduction is effected by a sexual process, which takes place in the following way:—Numerous little cavities, known as *conceptacles*, appear sunk in the surface of large swollen *receptacles* (*fig.* 5, *t*, *t*), on the ends of the longer forked branches of the Fucus, and in these are contained the *antheridia* or *oogonia*, or both of these organs, together with abortive filaments or *paraphyses*. Some species, as *Fucus platycarpus*, are monœcious, i.e. contain both antheridia and oogonia in the same conceptacle; but in others, as *Fucus vesiculosus*, either only antheridia or oogonia conceptacles are produced in the same plant; such species therefore are diœcious.

Taking *Fucus vesiculosus* as an example of the diœcious species, on making a section through a female conceptacle, its cavity is found to be of a more or less spherical form, and marked off from the loose tissue of the interior of the thallus by a thin layer of denser tissue resembling, and in fact being a continuation of, that of the surface, which may be called the *epidermal layer* (*fig.* 622). Springing from all parts of the wall of the conceptacle are slender jointed filaments, the *paraphyses*. Amongst these paraphyses are the *oogonia*, which are produced from certain cells of the lining, or epidermal layer of cells.

FIG. 622.

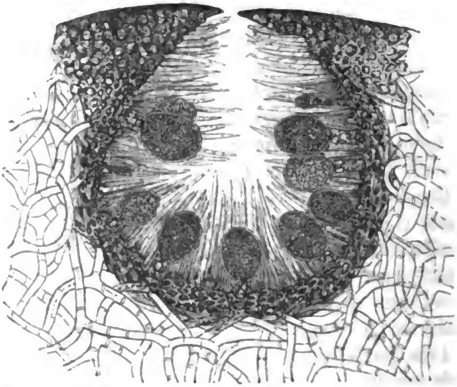


Fig. 622. Vertical section of a female conceptacle of ***Fucus vesiculosus*** containing oogonia and paraphyses. After Thuret.

The *antheridia* in the monœcious species, as *Fucus platycarpus*, are developed in the same conceptacle as the *oogonia*; and in diœcious species in separate conceptacles, then termed *male conceptacles*. These *antheridia* (*fig.* 623) are somewhat elliptical bodies, *a*, *a*, formed on branched hair-like cells. When mature the antheridium becomes of a bright red colour and contains a number of small antherozoids, each of which is furnished with a pair of cilia.

The *oogonia* are globular bodies borne upon a short one-celled stalk, in which are produced eight oospheres by means of the division of the contained protoplasm (*fig.* 624). These, which are at first angular, become rounded off, and are ultimately set free by the bursting of the oogonium membrane. The antherozoids (*fig.* 625), which escape almost simultaneously with the oospheres, gather round the latter, and appear to become finally blended with their substance. The *oospore* thus formed secretes around itself a cell-wall and very soon begins to germinate. Growth and division proceed, and so a new Fucus thallus is built up.

FIG. 623.

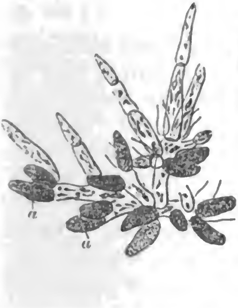


FIG. 624.

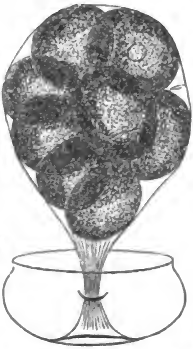


FIG. 625.

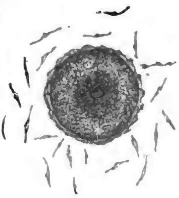


***Fig*. 623. Antheridia, *a*, *a*, on the branched hairs of the male conceptacle. After Thuret.——*Fig*. 624. Oogonium with the oospheres fully separated, and disengaging themselves from their coverings. After Thuret.——*Fig*. 625. An oosphere being fertilised by the antherozoids.**

BOOK II.

PHYSIOLOGY OF PLANTS; OR PHYSIOLOGICAL BOTANY.

HAVING examined the structure of plants, we have now to consider them in a state of life or action, and to explain, so far as science enables us, the laws which regulate their life, growth, and reproduction. The department of Botany which investigates these phenomena is termed Physiology; and the various processes which go on in the plant, and which are the necessary accompaniments of its life, are called its *functions*. Physiology includes the study of the life of the whole plant, when it is termed *general*; and that of the particular organs, in which case it is called *special*.

CHAPTER I.

SPECIAL PHYSIOLOGY OF THE ELEMENTARY STRUCTURES, AND OF THE ORGANS OF NUTRITION.

Section 1. PHYSIOLOGY OF THE ELEMENTARY STRUCTURES.

1. FUNCTIONS OF PARENCHYMATOUS CELLS.—As the simplest forms of Vegetable life, such as the Red Snow Plant (*Protococcus nivalis*) (*fig.* 1), consist of a single

cell of a parenchymatous nature, such a cell is necessarily capable of performing all the actions appertaining to plant life. Parenchyma also constitutes the whole structure of Thallophytes, as well as the soft portions of all plants above them; hence the physiology of parenchymatous cells is of the first importance. The more important vital actions of these cells are, 1. Formation of new cells; 2. Absorption and transmission of fluids; 3. Movements in their contents; and, 4. Elaboration of their fluid contents, and production of the various organic compounds of plants.

(1.) *Formation of Cells* (*Cytogenesis*).—All plants, as we have seen (page 23), in their earliest conditions, are composed of one or more cells, hence all the organs which afterwards make their appearance must be produced by the modification of such cells, or by the formation of new ones.

Cells can only be formed from the thickened fluid called *protoplasm* which is contained in their interior, or has been elaborated by their agency; hence cells can in no case be formed without the influence of living organisms. The *cell-wall* takes no part in the formation of cells.

Cells commonly originate in one of two ways: either free in the cavities of older cells, or at least in the protoplasmic fluid elaborated by their agency; or by the division of such cells. The first is called *Free Cell-formation*; the second, *Cell-division* or *Cell-multiplication.*

A. FREE CELL-FORMATION.—We may distinguish two modifications of *free cell-formation.* 1. Free cell-formation from a nucleus; and, 2. Free cell-formation without the previous formation of a nucleus.

a. *Free Cell-formation from a nucleus.*—This mode was discovered by Schleiden, and the manner in which he describes it as taking place is as follows:—A portion of the protoplasm collects into a more or less rounded or somewhat oval form, with a defined outer border, thus forming the nucleus or cytoblast of the cell; upon this a layer of protoplasm is deposited, which assumes the form of a membrane, and expands so as to form a vesicle; on the outside of this a cellulose membrane is secreted, and the formation of the cell is completed.

b. *Free Cell-formation without a previous nucleus.*—In the process of free cell-formation, as described above, the production of the nucleus is regarded as the first step of the process. But Henfrey does not consider the nucleus of any physiological import in free cell-formation, which process he thus describes:—'The essential character of free cell-formation lies in the circumstance that the protoplasm which produces the primary cellulose wall of the new cell previously becomes separated from the wall of the parent cell, so that the new cell is free (or loose) in the cavity of the parent cell.' In some cases, it is certain, no nucleus can be detected in a cell previous to the formation of other cells free in its cavity; hence the presence of the nucleus cannot be regarded as essential, but the portion of protoplasm, which in such cases separates from the general mass, must be capable of covering itself with a membrane and forming a cell.

In Flowering Plants free cell-formation occurs in the embryo-sac, in which part the germinal vesicles, the antipodal cells, and the cells of the albumen (endosperm), thus originate. In Flowerless Plants it is the mode by which the spores in the asci of Fungi (*fig.* 606) and Lichens (*fig.* 610) originate.

B. Cell-division.—This mode of cell-formation is also called by authors *parietal*, and *merismatic* or *fissiparous, cell-formation.* Cell-division can only take place in cells in which the contained protoplasm is in an active state, as in the cells of the *meristem*, a name given to that kind of parenchyma the constituent cells of which are thus capable of multiplying by division (see page

82). It may be treated of under two heads, namely: 1. *Cell-division without absorption of the walls of the parent cell*; and 2. *Cell-division with absorption of the walls of the parent cell, and the setting free of the new cells.*

a. *Cell-division without absorption of the walls of the parent cell.*—This mode of cell-formation takes place as follows:—The protoplasm of the cell, or, according to Mohl and Henfrey, the primordial utricle, becomes gradually constricted on the sides so as ultimately to form a sort of hour-glass contraction, and thus to divide the original contents into two distinct portions (*fig.* 626, *a*, *b*, *c*, *d*). Each portion of the protoplasm or of the primordial utricle then secretes a layer of cellulose over its whole surface; and where this is in contact with the original wall of the primary cell, it forms a new layer interior to it; but where away from the wall, at the new septum, a distinct cell-wall, so that the partition is double. The original cell thus becomes divided into two, and forms two cells, each of which has the power of growing until it reaches the original size of its parent, and then either, or both, may again

FIG. 626.

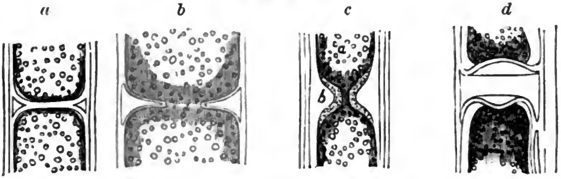


Fig. 626. *a.* Cell of *Conferva glomerata*, with the cell-contents constricted by the half-completed septum. *b.* A half-completed septum in which a considerable deposition of cellulose has already taken place. *c.* A septum in course of development, after the action of an acid, which has caused contraction both of the primordial utricle (*b*), and the cell-contents (*a*). *d.* Complete septum split into two lamellæ by the action of an acid. After Mohl and Henfrey.

divide, and each of the newly-formed cells grows in a similar manner to the size of its parent.[1]

In this mode of cell-formation it is by no means evident what function the nucleus performs in all cases. That *in some cases* it is unimportant is clear, because cell-division, as above described, may take place, as it does in some of the lower orders of plants, without the presence of a nucleus. In the higher orders of plants, however, the original nucleus of the cell generally undergoes subdivision into two halves, as is the case with the other contents, so that a nucleus is thus formed for each new cell into which the parent cell has been divided. But in other cases, separate nuclei are formed for the secondary cells, instead of the original nucleus dividing into two.

From recent observations Strasburger considers that the division of the nucleus and cell-formation are two processes which are quite distinct, and may be separated from each other, although in many cases they may come into contact.

It is by this process of cell-division that all the growing or vegetating parts of plants, whether Flowering or Flowerless, are produced and increased.

b. *Cell-division with absorption of the walls of the parent cell, and the setting free of the new cells.*—The pollen cells of all Flowering Plants, and the spores of the higher Flowerless Plants, are formed by this process, which only occurs in connexion with the organs of reproduction. The manner in which it commonly takes place in the production of pollen cells has already been described at pages 243 and 244 of this volume. The manner in which spores are formed in the higher Flowerless Plants is substantially the same in most cases. It sometimes happens, however, that in the development of pollen and spores, the special parent

---

[1] It should be noticed that the primordial utricle of Mohl here referred to differs from that defined by us at page 27 of this volume. Thus, according to the views adopted by us, the primordial utricle is characterised as the thin layer of protoplasm which lines the cell-wall after the cell has grown too large to be filled by protoplasm alone; while Mohl regards it as a more or less thickened layer of protoplasm, having the appearance of a membrane lining the cellulose wall, and enclosing the ordinary protoplasm of the cell.

FIG. 627.

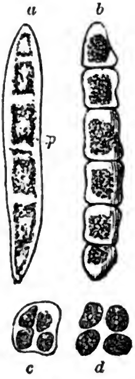


FIG. 628.

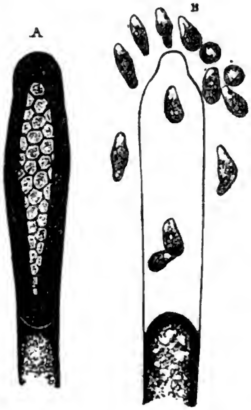


Fig. 627. *a*. Cylindrical cell from which are formed the parent cells of the spores of *Marchantia polymorpha*. *p*. Protoplasm of the parent cells. *b*. The same cell converted into a string of cells. *c*. One of the parent cells isolated. *d*. The four spores free. After Henfrey.——*Fig*. 628. Zoosporangia of *Achlya prolifera*. A. Still closed. B. The zoospores escaping. After Carpenter.

cells are not formed, as has been shown by Henfrey in the spores of *Marchantia polymorpha* (*fig*. 627).

In other cases, instead of the development of only four secondary cells in the cavity of the parent cell, the whole mass of the protoplasm may break up into a great number of small particles, as in the production of the swarm-spores of many Algæ (*fig*. 628) and Fungi. In this case the new cells (primordial) are only clothed by a cellulose wall after their separation from the parent or mother-cell. Some of these modifications of the process of cell-division are closely analogous to the ordinary process of *free cell-formation*, to which by many authors they are referred.

FIG. 629.

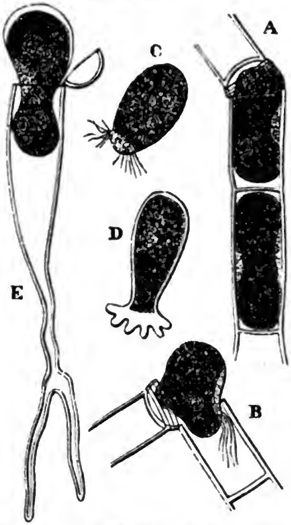


Fig. 629. A, B. Escape of the swarm-spores of an *Œdogonium*. C. One in free motion. D. The same after it has become fixed, and has formed the attaching disc. E. Escape of the whole protoplasm of a germ-plant of *Œdogonium* in the form of a swarm-spore. After Pringsheim.

c. Another method of cell-formation is that which is termed *rejuvenescence* or *renewal* of a cell, where the whole contents of a cell contract and expel a portion of the water of the cell-sap, the arrangement of the differentiated protoplasmic body is changed, and its whole form alters as it escapes from the cell-wall and eventually forms a fresh cell-wall (*fig.* 629, E). This process may be well seen in the swarm-spores of *Œdogonium*.

The production of a *zygospore*, which occurs in the process of conjugation, as already noticed in *Spirogyra* (*fig.* 620), is also another method of cell-formation. It occurs frequently in Algæ and various groups of Fungi.

(2.) *Absorption and Transmission of Fluids.*—The cell-wall of all young and vitally active cells is capable of readily imbibing fluids, and we find, accordingly, that liquid matters are constantly being absorbed and transmitted through such cells. The power which thus enables cells to absorb and transmit fluids is called *osmose*. It is, moreover, by a somewhat analogous process (*diffusion of gases*) that the cells on the surface of the plants are enabled to absorb and transmit gaseous matters.

FIG. 630.

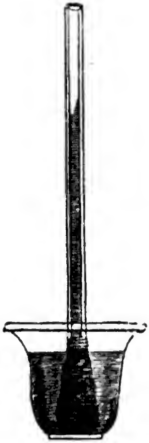


Fig. 630. Apparatus to show *osmotic action.* It consists of a bladder filled with syrup, to the open end of which a tube is attached and the whole placed in a vessel containing water.

Osmose may be explained as follows:—Whenever two fluids of different densities are separated by a permeable membrane which is capable of imbibing them, there is always a tendency to equalisation of density between the two, from the formation of a current in both directions, which will be modified by the action of the membrane, as well as by their own rates of diffusion. This osmotic action may be easily observed, by filling a bladder with coloured syrup, attaching to its open end a glass tube, and then immersing it in a vessel containing water (*fig.* 630). Under such circumstances the volume of the denser fluid in the interior of the bladder becomes increased (as will be at once seen by its rise in the tube), by the more rapid passage through the membrane of the thinner fluid than of the thicker, though at the same time a less portion of the syrup passes out into the water or thinner fluid, as may be proved by the sweet taste and colour which the latter gradually acquires. This double current will continue as long as there is any material difference of density between the two liquids. The stronger ingoing current is termed *endosmose*, and the weaker outgoing current *exosmose*. If the position of the liquids be reversed, the currents will be reversed in like manner, the preponderating current, in almost all cases, being that which sets from the thinner to the denser liquid.

The absorption and transmission of liquid matters through cells is now easy to explain, for as the fluid contents of the cells of the roots of plants are denser than the water contained in the media in which they grow, they will continually absorb the latter by endosmose; and as the changes which are going on in the cells of plants by evaporation, assimilation, and other processes, tend to thicken their contained liquids, there will also be a constant passage of the absorbed fluids from cell to cell towards those parts where such processes are taking place. The laws of ordinary *adhesive* or *capillary attraction* and of the *diffusion of fluids* also regulate the flow of the juices, which in certain cases may be even set in motion by either force. The action, however, of the intervening membrane (cell-wall), in greatly modifying or even overcoming osmotic action, is evidenced by the numerous cases in which neighbouring cells contain different substances without their intermixture. In cellular plants, such as Algæ and Fungi, absorption may take place at any part of the thallus; while in vascular plants it occurs principally through the roots, though all the green parts may contribute to it (see page 389), and that, too, probably independently of the presence or absence of stomata.

(3.) *Movements of the Cell-contents.*—In many cells, and probably in all at a particular period of their life, when they are in a vitally active state, a kind of movement of a portion of their contents takes place. This movement is due to a circulation of the protoplasm, which is rendered visible by the opaque granular particles which it contains (*figs.* 631 and 632). The protoplasm thus circulating does not pass from one cell to another, but is strictly confined to the cell in which it originates. This kind of movement has been termed *Rotation*, *Gyration*, or *Intracellular Circulation* ; it ceases, in the generality of cases, in cells when they have attained a certain size, but in those of many aquatic plants it continues throughout their life.

The appearances presented by these movements vary in different cases. Thus, in the cells of many hairs, as in those of *Althæa rosea* (*fig.* 631), the protoplasm becomes hollowed out, and the motion is in reticulated currents, radiating apparently from, and returning to, the nucleus ; to this action the term *circulation* is applied. In the cells of the leaves of the *Vallisneria* (*fig.* 632) and *Anacharis*, and in those of other parts of the same plants, intracellular movements may be readily observed when they are submitted to a

FIG. 631.

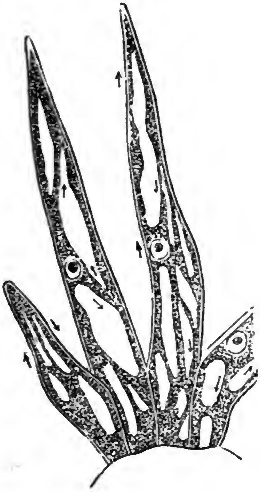


FIG. 632.

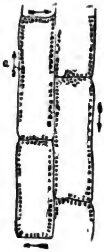


Fig. 631. Hair on calyx of flower-bud of *Althæa rosea.* The streaming of the protoplasm is indicated by the arrows. After Sachs.—*Fig.* 632. Cells of the leaf of *Vallisneria spiralis*, showing the circulating current with its granular contents, passing up one side of each cell, aross, and down on the other side. The direction of the currents is indicated by the arrows.

moderate microscopic power; here, however, the protoplasm does not become hollowed out, but with its granular contents will be seen to pass round the interior of the walls of each cell, retaining its activity permanently; this movement is called *rotation*. In the *Characeæ*, however, and especially in the *Nitellæ*, the moving protoplasm does not rotate round the walls, nor in reticular currents, but passes obliquely up one side of the cell (*fig.* 633) until it reaches the extremity, and then flows down in an opposite direction on the other side.

FIG. 633.

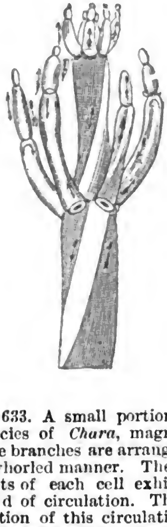


Fig. 633. A small portion of a species of *Chara*, magnified. The branches are arranged in a whorled manner. The contents of each cell exhibit a kind of circulation. The direction of this circulation is indicated by the arrows.

No satisfactory explanation has yet been brought forward to account for this movement, but it is unquestionably connected with the vitality of the cell-contents, and all agents that actually injure the cell will generally stop it at once, and permanently, though in some plants (as *Chara*) a large cell may be tied across the middle with the effect of stopping the circulation temporarily; but after a short time it will recommence in each half.

4. *Elaboration of the Cell-contents.*—All cells exposed to light, heat, and air which contain protoplasm have the power of producing in their contents the different organic compounds which are concerned in the development of new tissues; and in the formation of others which have been termed secretions. (See page 403.) In old cells the secretions of the plant are also, in part, deposited.

2. FUNCTIONS OF PROSENCHYMATOUS CELLS.—Prosenchymatous cells are especially adapted, by their construction and mode of combination into a tissue, for giving strength and support to plants. In a young state also, before their walls are thickened, they appear to be the main agents by which the fluids absorbed by the roots are carried upwards to the leaves and other external organs, to be elaborated by the agency of heat, light, and air. This, however, is doubted by some experimenters. (See *Functions of Vessels*, below.) The down current of elaborated sap is generally believed to pass through the liber-cells of the inner bark.

3. FUNCTIONS OF VESSELS.—The functions of the spiral, annular, reticulated, pitted, and scalariform vessels have been a subject of much dispute from an early period, and have been repeatedly investigated. Hales, Bischoff, and others came to the conclusion that these vessels were carriers of air, and it is certain that air alone is found in old vessels; while Dutrochet, Link, Rominger, &c., believed that their essential function was to carry fluids from the root upwards, which views from recent observations appear to be correct. According to Link, when plants are watered for several days with a solution of ferrocyanide of potassium, and afterwards with a solution of persulphate of iron, prussian blue is found in the vessels, and not in the prosenchymatous cells, as the experiments of Hoffmann, alluded to in speaking of the functions of prosenchymatous cells, seem to indicate; and, more recently, the experiments of Herbert Spencer, conducted with great care, tend to show that, in young plants at all events, the vessels are the chief sap-carriers, whence the fluid exudes into the surrounding prosenchyma.

Functions of Laticiferous Vessels.—The physiological importance of these vessels has given rise to much discussion, and is still involved in obscurity. But it would appear that these vessels, as also others which are closely allied to them, as *sieve vessels* and *vesicular* *vessels*, act as reservoirs of nutrient fluids, and also as carriers of such fluids to those parts of plants where they are required.

4. FUNCTIONS OF EPIDERMAL TISSUE.—The special functions of epidermal tissue are :—to protect the tissues beneath from injury, and from being too rapidly affected by atmospheric changes; to regulate the transpiration of watery fluids; to absorb and exhale gaseous matters; and probably, to some extent, to absorb water. The epidermis itself is specially designed to prevent a too ready evaporation of fluid matters from the tissues beneath, and hence we find that it is variously modified to suit the different conditions to which plants are submitted. But while the epidermis generally has for its object the restraining of a too abundant exhalation, the *stomata* are especially designed to facilitate and regulate the passage of fluid matters, and in proportion to their number, therefore, upon the different organs and parts of plants, *cœteris paribus*, so will be the exhalation from them.

It is also through the cells of the epidermis, and more especially through the stomata, that certain gaseous matters are absorbed from, and exhaled into, the atmosphere, in the processes of Respiration and Assimilation. (See pages 309 and 402.)

It has long been a disputed question whether the epidermal tissue and its appendages have the power of absorbing liquids, such as water. But the recent researches of Henslow seem to prove that leaves can absorb moisture. (See page 399.) Indeed, it is very difficult to account for the immediate recovery of drooping plants in a greenhouse when water is sprinkled upon the floors, or the revival in nature of vegetation when a mist follows a long succession of dry weather—except on the supposition that watery vapour is taken up by the epidermal tissue and its appendages, unless the presence of moisture acts only in the way of checking transpiration.

Origin and Development of Stomata.—A stoma is formed by the division of an epidermal cell (the mother-cell) by a partition which extends across and divides the two daughter- or sister-cells (*fig.* 634, s); this partition then becomes thickened, especially at the angles where it joins the walls of the parent-cell. After a time the thickened partition becomes laminated, when a cleft appears in it, narrower in the middle, wider without and within, which unites the intercellular space (*fig.* 634, D, s, *t*) with the external air. Before the parent cell divides, a cuticularisation of its surface also takes place, the cuticle extending over the apposed surfaces of the sister-cells, and the adjoining cells of the epidermis. Even when the division is complete, a portion (if the leaf is examined in a superficial position) still remains as a simple lamella. These two sister- or daughter-cells are called guard-cells, and further differ from the rest of the epidermis in containing chlorophyll and starch.

FIG. 634.

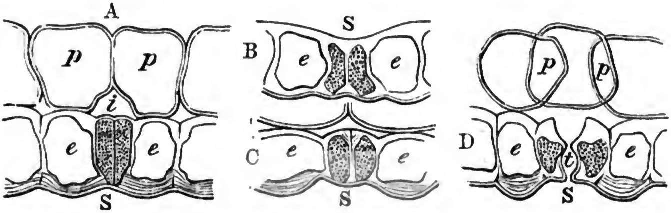


Fig. 634. *p, p.* Parenchyma of the leaf. *e, e.* Epidermis cells. S. Stoma. *i.* Air cavity. In these figures the development of the stoma of *Hyacinthus orientalis* is represented from the first division of the mother-cell in A into two daughter-cells, to the complete separation shown in D. After Sachs.

5. FUNCTIONS OF THE APPENDAGES OF THE EPIDERMIS. —*Hairs* and their modifications appear to be designed to protect the epidermis and parts beneath from injury due to cold and other external influences, hence we find young buds (page 99), &c., frequently coated with

hairs. Hairs also appear in certain instances, at least to some extent, to absorb fluid matters from the atmosphere, whilst in other cases they serve to assist the epidermis in restraining exhalation; and we find, accordingly, that plants which are densely coated with them are well adapted to grow in very dry situations, and to sustain without injury a season of drought.

Glands are those organs which in themselves secrete some peculiar matter. (See page 63.) These secretions are either permanently stored up in them, or excreted.

6. FUNCTIONS OF THE INTERCELLULAR SYSTEM.—The *intercellular canals*, except at those times in which the tissues of the plant are gorged with sap, as in the spring of the year, are filled with air, and the special function which they perform is to allow a communication between the external air and the contents of the internal tissues by virtue of the laws regulating the diffusion of gases. They likewise facilitate exhalation of liquid matters by their connexion with the stomata. The *intercellular spaces* are also, in most cases, filled with air; while the *air-cells* and *air-cavities*, as their names imply, are in like manner filled with aëriform matters, and in water-plants are especially designed to diminish the specific gravity of the parts in which they are found, and thus to enable them to float readily, or to be suspended in the water. The *receptacles of secretion*, as their name implies, contain the peculiar secretions of certain plants, and are closely allied in their nature to glands.

Section 2. PHYSIOLOGY OF THE ORGANS OF NUTRITION.

1. OF THE ROOT OR DESCENDING AXIS.—The offices performed by the root are:—1. To fix the plant firmly in the earth or to the substance upon which it grows, or, in some aquatic plants, to float or suspend it in the water. 2. To absorb liquid food. 3. According to some authors, to excrete into the soil certain matters which

are injurious, or at least not necessary for the healthy development of the plant, though in the earth they may assist subsequent absorption by dissolving substances which could not otherwise pass into the plant. 4. To act as a reservoir of nutriment.

The office which the root performs, of fixing plants in those situations where food can be obtained, is evident, and needs no further remarks.

Absorption by the Root.—The function which the root performs of absorbing food for the uses of the plant, from the materials in or upon which it grows, is not possessed by its whole surface, but is confined to the cells and root-hairs (*fig.* 163) of the newly developed portions and young parts adjacent to them; and even these parts can only absorb when they are in the closest contact with the particles of soil by the root-hairs. Hence in the process of transplanting, it is necessary to preserve the young growing rootlets as far as possible, otherwise the plants thus operated upon will languish or die, according to the amount of injury they have sustained.

This absorption of food by the youngest rootlets is due to osmose taking place between the contents of their cells and the fluids of the surrounding soil. (See page 384.)

Roots absorb more water than the plant requires, and this excess of fluid exerts a pressure up the stem called *Root pressure*, which may be measured by cutting off the upper part of the stem of a growing plant and attaching a manometer to the cut end. (See pages 418 and 419.)

Roots can only absorb substances in a liquid state, therefore the different inorganic substances which are derived from the soil, and which form an essential part of the food of plants, must be previously dissolved in water. If the roots of a freely growing plant be placed in water in which charcoal in the most minute state of division has been put, as that substance is insoluble in the fluid, it will remain on the surface of the roots, and the water alone will pass into them.

Selection of Food by Roots.—Numerous experimenters have proved that when the roots of living plants are put into mixed solutions of various salts, some will be taken up more freely than others. Again, though the seeds of the common Bean and Wheat be sown in the same soil, and exposed, as far as possible, to the same influences in their after-growth and development, yet chemical analysis shows that, the Wheat stalk contains a much larger proportion of silica (which it must have obtained from the soil) than that of the Bean.

The experiments of others, again, appear, on the contrary, to indicate that roots absorb all substances presented to them indifferently, and in equal proportions. But the simple fact, as just mentioned, which is easily proved by chemical analysis—that the ashes of different plants contain different substances or in very different proportions—seems to prove incontestably that roots have a power of selecting their food. In using the term *selecting*, we do not, however, intend to imply that roots have any inherent vital power of selection resembling animal volition, but only to express the result produced by virtue of the mutual actions of the root and the substances which surround it in the soil. This power or property of selection is without doubt due to some at present but little understood molecular relation which exists between the membranes of the cells of different plants and the substances which are taken up or rejected by them, different roots possessing different osmotic action for the same substances.

Excretion by Roots.—Roots seem to have no power of getting rid of excrementitious matters like that possessed by animals; but that they do throw off into the soil a portion of their contents by a process of exosmose, which appears to be an almost necessary result and accompaniment of the endosmose by which absorption takes place, is most probable. Carbon dioxide, and possibly other acid substances, are parted with by roots in this way; and thus assist subsequent absorption by dissolving substances which could not otherwise pass into the plant.

Storing of Nutriment by Roots.—Roots frequently act as reservoirs of nutriment in the form of starchy, gummy, and similar matters for the future support of the plant. The tubercules of the Dahlia and Orchis; and the roots of the Turnip, Carrot, and other biennials, are familiar illustrations.

Development of Roots.—The growing part of the root is called the *growing point* (*punctum vegetationis*). It is commonly spoken of as the apex of the root, but is not really so, since it is covered with a cap of cells, the *pileorhiza.* (See page 117.) The cells composing it consist of *primary meristem*; [1] they are thin-walled,

FIG. 635.

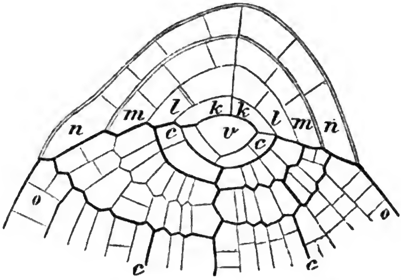


Fig. 635. Longitudinal section through the end of the root of *Pteris hastata*, showing apical region. *v*. Apical cell, from which are developed the tissue of the substance of the root, *o*, *c*, and the root-cap or pileorhiza, *k*, *l*, *m*, *n*. After Sachs.

---

[1] This name is given to that kind of meristem which forms the whole tissue of very young organs or parts of organs, in order to distinguish it from another kind of meristem, termed *secondary meristem* (page 82), which occurs in organs along with *permanent tissue*, or that tissue in which the cells are no longer capable of division.

filled with protoplasm, and are capable of division. Here, as in stems, and unlike leaves, the last formed part is towards the apex; hence the growth in length is indefinite, the difference between the *growing part* or so-called *apical cell* in roots and stems being that, in the former case, it or they (for there is frequently a group of apical cells) are covered by a cap of cells (*fig.* 635, *k*, *l*, *m*, *n*) formed from the distal or apex end of the so-called apical cell, *v*; whereas in stems there is no such cap. (See page 396, and *fig.* 636.)

2. OF THE STEM OR CAULOME.—The offices performed by the stem and its ramifications are:—1. To form a support for the leaves and other appendages of the axis which have but a temporary existence, and thus enable them to be freely exposed to the influences of light and air, which are essential for the proper performance of their functions and development; 2. To convey air and fluid matters upwards, downwards, and inwards, to those parts of plants where active chemical and other changes are going on; and 3. To act as a reservoir for the so-called secretions of the plant.

Special Functions of the different Parts of the Stem.—(1.) *The Medulla or Pith.*—Various functions have at different times been ascribed to the pith. In the young plant, and in all cases when newly formed, the cells of the pith are filled with a greenish fluid containing nutrient substances in a state of solution; but as the pith increases in age it loses its colour, becomes dry, and is generally more or less destroyed. The pith, therefore, would appear to serve the temporary purpose of nourishing the parts which surround it when they are in a young state; and in some cases it seems also to act as a reservoir of the so-called secretions of the plant.

(2.) *The Wood.*—The wood, when in a young and pervious condition (*alburnum*), is the main agent by which the crude sap is conveyed upwards to the external organs to be aërated and elaborated; but whether the passage is primarily by the vessels or the prosenchymatous cells is disputed. (See page 387.) As the wood increases in age, and becomes heart-wood or duramen, the tissues of which it is composed become thickened and altered in various ways, by which they are more or less hardened and solidified, and in this manner the stem acquires strength and firmness, but the tissues are no longer physiologically active, and are in fact useless as carriers of sap.

Formation of Wood.—On the outside of the young wood, but organically connected with it and with the liber of Dicotyledons, is the vitally active layer of cells called the cambium layer (page 82), from which are annually formed new layers of wood and inner bark. The cells of the cambium layer are filled in the spring, and at other seasons when growth takes place, with elaborated sap, or that sap which contains all the materials necessary for the development of new structures. Great differences of opinion exist amongst botanists as to the exact manner in which wood is deposited, but they are nearly all agreed that the materials from which it is formed are elaborated in the leaves, that without leaves there can be no additions to it, and that in proportion to their amount so will be the thickness of the wood.

Herbert Spencer believes that intermittent mechanical strains, such as those produced by the wind, are the sole cause of the formation of wood, which is developed to resist the strains. His experiments were anticipated by Knight so far back as 1803; but his results must be taken with modification. It is probably true that such a conservative formation of wood does occur to meet unusual strains; but the want of correspondence in nature between great exposure to such strains and large deposit of wood, and the numerous examples of great wood-formation in ligneous twiners and nailed-up trees must prevent us from considering it an all-sufficient explanation.

(3.) *The Medullary Rays.*—The functions which these rays perform is probably to assist the diffusion of a portion of the elaborated sap from the bark and cambium layer through the wood, in which certain of the organic compounds or secretions it contains are ultimately deposited.

(4.) *The Bark.*—The bark acts as a protection to the young and tender parts within it. The inner part is generally believed to convey the elaborated sap from the leaves downwards, in order that new tissues may be developed, and the different secretions deposited in the wood and in its own substance. The inner bark frequently contains very active medicinal substances, and others which are useful in the arts &c.

FIG. 636.

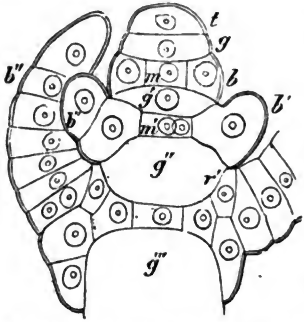


Fig. 636. Longitudinal section through the apical region of three primary shoots of *Chara fragilis.* *t.* Apical cell, in which segments are formed by septa, each segment being further divided by a curved septum into a lower cell not further divisible, which develops into an internode, *g*, *g'*, *g''*, *g'''*, and an upper cell which produces a node, *m*, *m'*, and the leaves, *b*, *b'*, *b''*, *b''*, which also undergo segmentation. After Sachs.

Development of the Stem.—The stem is developed from the apex or growing point (*punctum vegetationis*), where is situated the apical cell or apical groups of cells. In most of the Cryptogamia growth is effected by the division of a single *apical cell* (*fig.* 636), which is generally large, and divides into two daughter-cells, one of which becomes the new apical cell, while the other, the *segment-cell*, by further division forms the permanent tissue. In the stems of the higher plants, instead of a *single* apical cell, there are generally several such cells, which differ from the like cells of roots in having no special cap, and from leaves in the fact that the cells last formed are at the apex. (See *Development of Roots*, page 393; and *of the Leaves*, page 409.)

3. Of the Leaves.—The essential functions of the leaves are:—1. The exhalation of the superfluous fluid of the crude sap in the form of watery vapour; 2. The absorption of fluid matters; 3. The absorption and exhalation of gases; and 4. The formation of the organic compounds which are concerned in the development of new tissues, and in the formation of the various secretions of plants. These functions they are enabled to perform through the influence of heat, air, and light, to which agents, by their position on the ascending axis of the plant, and by their own structure, they are necessarily, under ordinary circumstances, freely exposed.

(1.) *Exhalation of Watery Vapour by Leaves.*—The immediate object and effect of this process, which is commonly termed *transpiration*, is the thickening of the crude sap, and the consequent increase of solid contents in any particular portion of it. This transpiration of watery vapour, as already noticed (see page 388), takes place through the stomata, and hence as a general rule the quantity transpired will be in proportion to their number. The presence or absence of a true epidermis and the various modifications to which this is liable, have also an important influence upon the transpiration of fluid matters.

From some interesting experiments of M. Garreau on transpiration of leaves, he was led to draw the following conclusions:—1. The quantity of water exhaled by the upper and lower surfaces of the leaves is usually as 1 to 2, 1 to 3, or even 1 to 5, or more. The quantity has no relation to the position of the surfaces, for the leaves, when reversed, gave the same results as when in their natural position. 2. There is a correspondence between the quantity of water exhaled and the number of stomata. 3. The transpiration of fluid takes place in greater quantity on the parts of the epidermis where there is least waxy or fatty matter, as along the line of the ribs.

This transpiration of fluid is influenced to a great extent by the varying conditions of the atmosphere as to moisture and dryness; thus, if two plants of the same nature are submitted to similar conditions, except that one is placed in a dry atmosphere, and the other in a moist, the former will give off more fluid than the latter, though, according to M'Nab, a plant exposed to the sun will transpire most in a moist atmosphere; while in the shade, an atmosphere loaded with vapour causes transpiration to cease. The great agent, however, which influences transpiration is light. Daubeny also found that the different rays of the solar spectrum had a varying influence, the illuminating rays having more effect than the heating rays. But the result of M. Weisner's experiments show that the action of light on transpiration is greatly increased by the presence of chlorophyll; that they are not the most luminous rays, but those which correspond to the absorption band of the chlorophyllian spectrum, which excite transpiration; and finally, that the rays which pass through the chlorophyll solution exerted but little effect on transpiration.

The quantity of fluid thus exhaled or transpired by the leaves has been the subject of various experiments. The most complete observations upon this point were made by Hales so long ago as 1724. He found that a common Sunflower 3½ feet high, weighing 3 pounds, and with a surface estimated at 5,616 square inches, exhaled, on an average, about twenty ounces of fluid in the course of the day; a Cabbage plant, with a surface of 2,736 square inches, about nineteen ounces per day; a Vine with surface of 1,820 square inches, from five to six ounces; and a Lemon tree, exposing a surface of 2,557 square inches, six ounces on an average in a day.

The fluid which thus passes off by the leaves of plants is almost pure water. This transpiration of watery vapour must not be confounded with the excretion of water containing various saline and organic matters dissolved in it, which takes place in certain plants, either from the general surface of their leaves, or from special glands. In the peculiarly formed leaves of *Dischidia*, *Nepenthes*, *Sarracenia*, and *Heliamphora*, watery excretions of this nature always exist. From the extremities or margins of the leaves of various Marantaceæ, Musaceæ, Araceæ, Graminaceæ, and other plants, water is also constantly excreted in drops at certain periods of vegetation; but this may be due in certain cases to root-pressure caused by the great amount of fluid absorbed. But the most remarkable plant of this kind is the *Caladium distillatorium*, from which half a pint of fluid has been noticed to drop away during a single night, from orifices placed at the extremities of the leaves, and communicating freely with internal passages.

(2.) *Absorption of Fluids by Leaves.*—The recent researches of Henslow, as already noticed (page 388), seem to prove conclusively that both leaves and green internodes are capable of absorbing a large amount of moisture, and that probably the quantity absorbed is independent of the presence or absence of stomata.

(3.) *Absorption and Exhalation of Gases by Leaves.*—We have already noticed (p. 391) the property possessed by the roots of absorbing liquid food from the medium in which they grow, and also their supposed power of excretion (p. 392). Whilst plants are thus intimately connected by their roots with the soil or medium in which they are placed, they have also important relations with the atmosphere by their leaves and other external organs, which are constantly absorbing from, or exhaling into it, certain gases. The atmosphere, it should be remembered, is brought into communication with the interior of the leaves by the stomata; and in this way fills the whole intercellular structure of these organs much in the same way as the air fills the lungs of an animal. The gases which are thus absorbed and exhaled by the leaves and other green organs and parts of plants are essentially carbon dioxide and oxygen. The experiments of Boussingault would also indicate that, in some cases at least, carbon oxide is evolved with the free oxygen. Draper and many others likewise believe that leaves and other parts exhale nitrogen when exposed to sunlight. Plants, under certain circumstances, may also absorb nitrogen from the air, though it does not then serve for nutrition, but the investigations of Lawes, Gilbert, Daubeny, and Pugh tend, on the contrary, to negative this statement. The amount of nitrogen found in plants is greater, however, than can be accounted for by the quantity of nitrogen supplied to the soil by rain, and is doubtless partly due to the absorption of ammonia from the soil, as also, probably, partly by the leaves, according to Sachs and Meyer, whose observations have been confirmed by Schlösing.

The absorption and exhalation of carbon dioxide and oxygen gases by the leaves vary according to the circumstances in which they are placed. Thus, when the green leaves of a healthy plant are exposed to sunlight, all experiments show that carbon dioxide is absorbed from the atmosphere and decomposed, leaving its carbon, which is the result of the decomposition, behind, and evolving its oxygen. These changes do not take place in the deep-seated tissues of the plant, nor in the epidermal cells, but in those only beneath the latter. This decomposition of carbon dioxide is effected by the influence of chlorophyll; for when leaves are not green, as is the case in many parasitic plants and in those which are more or less blanched, they, like the other parts of a plant in a similar condition, are incapable of assimilating, and must therefore procure their nutriment from already assimilated materials.

This absorption of carbon dioxide with fixation of carbon and evolution of oxygen is in direct proportion to the intensity of the light to which the plants are exposed; but the experiments of Draper, Hunt, and others, show that the different rays of the spectrum have a varying influence in promoting such a decomposition. Thus Draper concluded by his experiments that the illuminating rays have the greatest effect in promoting decomposition of carbon dioxide, those nearest them much less so, and the heating and chemical rays none at all. The experiments of Cloez and Gratiolet lead substantially to the same conclusions. Some heat, however, is necessary for this decomposition, and within certain limits it is found that a slight increase of heat will compensate for a corresponding diminution of active light rays. (See also *The Effect of the Electric Light on the Growth of Plants*, &c.)

Whilst the absorption of carbon dioxide and evolution of oxygen are thus taking place by day, it is supposed by most observers, that in the absence of light a contrary action occurs—oxygen being then absorbed, and carbon dioxide exhaled. At the same time, all who hold this opinion admit, that the amount of oxygen gas thus absorbed by night is very much less than that given off by day.

Some authors, again, maintain that carbon dioxide is given off by the leaves in varying quantities, both by day and night; whilst others deny that leaves, at any time when in a healthy state, give off carbon dioxide.

Those, again, who hold the opinion that leaves when exposed to solar light give off oxygen, in consequence of the absorption and decomposition of carbon dioxide, and that a contrary change takes place by night—maintain different views upon the nature of these changes. Some of them regard the evolution of oxygen by day as a true *vegetable respiration*, and hence look upon vegetable respiration as producing results upon the atmosphere diametrically opposite to those of animal respiration. Others, such as Mohl and Henfrey, say that here we have two distinct functions going on—*one*, taking place by day, and consisting in the consumption of carbon dioxide, with fixation of carbon and evolution of oxygen; and *another*, only occurring by night, in the leaves and other green parts, but also by night and day in those not green, and which consist in the absorption of oxygen and evolution of carbon dioxide. The former function they regard as a process of *assimilation*, and the latter as *respiration.*

Those who maintain that carbon dioxide is exhaled both by day and night, regard this as true vegetable respiration; and the exhalation of oxygen by day, as due to assimilation; while those who deny that carbon dioxide is ever given off by healthy leaves, regard the exhalation of oxygen gas as vegetable respiration.

It will be seen from the above abstract of the opinions of different physiologists, that various ideas are entertained by them as to the action of the leaves and other green organs under different degrees of light; and also upon the character of such changes. Generally, it may be stated—that all agree as to the evolution of oxygen by the leaves and other green parts of plants under the influence of solar light with the fixation of carbon, to which process the term *assimilation* is applied in this volume in accordance with the views now commonly entertained by botanists; while that of *respiration* is here used to denote the absorption of oxygen and evolution of carbon dioxide, which takes place both by night and day, but is most evident by night, because the large quantity of oxygen given off during the day in the process of assimilation obscures the former change. (See page 420.)

(4.) *Formation of Organic Compounds by Leaves.*—By the alterations produced in the watery contents of the green leaves and other green parts of plants, by exposure to air, heat, and light, the matters which they contain are left in a state prone to change, and therefore freely combine together. By this means the different organic compounds are produced which are directly concerned in the development of new tissues; and in the formation of others, such as resinous matters, various acids, numerous alkaloids, colouring matters, &c., which, so far as we know at present, perform no further active part in the plant, and are accordingly removed from the young and vitally active parts, and either stored up in the older tissues, and hence frequently termed *secretions*, or removed altogether from the plant as *excretions*. The production of these organic substances takes place by *assimilation* and *metastasis*. (See page 420.) We see, therefore, that without leaves or other analogous green organs no growth to any extent could take place, or any peculiar secretions be formed; but it must be also recollected that without the exposure of even the leaves to light, no proper assimilation of the various matters taken up by the plant can be effected; for instance, if a plant be put into the dark, it becomes blanched (*etiolated*), in consequence of the non-development of chlorophyll properly so called (page 405), and, moreover, no woody matter is then formed, and but few of its peculiar secretions. The recent experiments of Pringsheim tend to show that the earliest nutritive product produced by the influence of light, heat, and air is formed in the interior of the chlorophyll grains. This principle he has termed *hypochlorin*, and by its oxidation he believes that all nutritive bodies such as starch, dextrose, and oil, are formed. It is also supposed by Pringsheim that the function of the green colouring matter is to act as a screen, and to reject the rays of the spectrum favouring oxidation, and to allow those only to pass which aid nutrition.

How such a vast variety of organic compounds can be formed in plants, is at present almost unknown. It is, however, certain that the elimination of oxygen and carbon dioxide, already described, are results of these chemical processes. The food of plants is highly oxygenated as compared with the important proximate principles formed within their leaf-cells, and hence a disengagement of oxygen must occur during their formation.

(5.) *Effects of Gases generally upon Leaves.*—We have now seen that the ordinary normal constituents of atmospheric air, namely, carbon dioxide, oxygen, nitrogen, and ammonia, in certain proportions, are those which are especially necessary for the due elaboration of the various organic compounds of plants, and these we have also shown are absorbed by the leaves or roots. It is by leaves especially that carbon, which is so essential to plants, and which enters so largely into the composition of its various organic compounds, is absorbed. But it must be understood, at the same time, that plants will not live in an atmosphere composed simply of either carbon dioxide, oxygen, or nitrogen; but that for their proper development, these gases must be mixed in suitable proportions; for if either of them be in great excess, the plants will either languish or perish, according to circumstances.

While the above gases in suitable proportions are necessary to the due performance of the proper functions of plants, all other gases when mixed in the air in which they are placed, appear to act more or less injuriously upon them. This is more particularly the case with sulphurous acid and hydrochloric acid gases, even in small quantities; but an atmosphere containing much ammonia, common coal gas, &c., also acts prejudicially.

The action of sulphurous and hydrochloric acid gases upon plants appears to resemble that of irritant poisons upon animals, thus they first exert a local action upon the extremities of the leaves, and this influence is soon communicated to the deeper tissues, and if the plants be not removed into a purer air, they will perish; but when such gases are not in great quantities, if the plants are speedily removed from their influence, they usually revive, the parts attacked being alone permanently injured.

While the gases thus mentioned act as irritant poisons upon plants, sulphuretted hydrogen, carbon oxide, common coal gas, and others, seem to exert an influence upon them like that produced by narcotic poisons upon animals, for by their action a general injurious influence is produced on their vitality, and a drooping of the leaves, &c., takes place; and, moreover, when such is the case, no after removal into a purer air will cause them to revive.

As the above gases are constantly present in the air of large towns, and more especially in those where chemical processes on a large scale are going on, we have at once an explanation of the reason why plants submitted to such influences will not thrive. The air of an ordinary sitting room, and especially one where gas is burned, is also rendered more or less unsuitable to the healthy growth of plants, in consequence of the production of injurious gases as well as from the dryness of the atmosphere.

(6.) *Colour of Leaves.*—The green colour of leaves is due to chlorophyll contained in the cells situated beneath the epidermis; and hence the leaves and other parts of plants grown in darkness are blanched or etiolated (p. 403). Although no chlorophyll, properly so called, is formed in the absence of light, the protoplasm within the cell-walls becomes differentiated into granules, which, however, remain colourless or yellow until exposed to light, and then become of a green colour, in consequence of the formation of true chlorophyll. To this rule there are some notable exceptions—viz., the germinating seeds of many Coniferæ and the fronds of Ferns, which will become green even in total darkness, provided that the temperature is sufficiently high. The rapidity with which leaves become green generally, and the intensity of their colour, will be in proportion to the amount of light and heat (25°–30° C. being about the maximum) to which they have been exposed. It has been also shown that iron is necessary for the production of chlorophyll. (See also *The Effect of the Electric Light on the Growth of Plants*, &c.)

The different rays of the spectrum have also a varying influence in promoting the formation of chlorophyll. Some difference of opinion exists as to those rays which are most active in this respect, but nearly all experimenters agree, that the illuminating or yellow rays, namely, those which, as we have already seen (page 401), have the greatest effect in promoting the decomposition of carbon dioxide, are those also which are the most active in the production of chlorophyll.

M. Frémy has investigated the nature of chlorophyll, and, according to him, it is composed of two colouring principles—one a yellow, which he has termed *phylloxanthin*; and the other a blue, which he has called *phyllocyanin* (see page 28). Both these principles have been isolated by M. Frémy, who has also endeavoured to show that the yellow colour of etiolated and very young leaves is due to the presence of a body which he has termed *phylloxanthéin,* and which is coloured blue by the vapour of acids. The same principle results from the decoloration of phyllocyanin ; hence it would seem that phyllocyanin is not an immediate principle, but that it is formed by the alteration of phylloxanthéin. The experiments of M. Filhol do not, however, altogether correspond with those of M. Frémy, whilst the more recent spectroscopic investigations of Professor Stokes and H. L. Smith tend to show that chlorophyll is more complex than M. Frémy imagined.

Chlorophyll is stated by Sorby to exist in a blue and also in a yellow state, giving different effects with the spectroscope. *Chlorofucin* is another colouring matter, which, like the two preceding, is fluorescent, and has a yellow-green colour. These three are soluble in alcohol, but not at all in water, and not always in bisulphide of carbon. Sorby also describes other colouring matters which are soluble in bisulphide of carbon, and give different results to the foregoing with the spectroscope.

The autumnal tints of leaves, which are generally some shades of yellow, brown, or red, are commonly regarded as due to varying degrees of oxidation of the chlorophyll which their cells contain, to which change Henfrey applied the term 'decay of chlorophyll.' The experiments of M. Frémy show that the yellow leaves of autumn contain no phyllocyanin, and hence that their colour is entirely due to the phylloxanthin, either in its original condition or in an altered state. Strong light may also produce a fading of leaves and other green parts, which change appears to be due to an alteration in the position of the grains of chlorophyll in the cells.

When leaves are of some other colour than green, the different colours are produced either by an alteration of the chlorophyll or of one of the principles of which it is formed, or in consequence of the presence of some other colouring agent.

Variegation in leaves must be regarded as a diseased condition of the cells of which they are composed; it is commonly produced by hybridisation, grafting, differences of climate, soil, and other influences. The variegated tints are due either to the presence of air in some of the cells, or more commonly to an alteration of the chlorophyll of certain cells, or one of the substances of which chlorophyll is composed. (See also *Colour of Flowers.*)

(7.) *Defoliation or Fall of the Leaf.*—Leaves are essentially temporary organs; for, after a certain period, which varies in different plants, they either gradually wither upon the stem, or they separate from it by means of an articulation; in the former case they are said to be non-articulated; in the latter articulated (see page 130). This fall of the leaf is commonly termed *defoliation*.

The cause or causes which lead to the *death* of the leaf are by no means well understood. The opinion commonly entertained is this: the membrane constituting the walls of their cells gradually becomes so incrusted by the deposit of earthy and other matters which are left behind by the fluid substances which are contained in or transmitted through them, that ultimately the tissues of the leaf become choked up and are no longer able to perform their proper functions, and the leaf then begins to dry up. After its death the leaf may either fall, or remain attached to the stem, as already observed.

The *fall* of the leaf does not, then, depend upon the death of the organ; it may occur before death, or may not take place at all. When it happens, it is dependent on an organic separation or articulation which Asa Gray thus describes:—'The formation of the articulation is a vital process, a kind of disintegration of a transverse layer of cells, which cuts off the petiole by a regular line, in a perfectly uniform manner in each species, leaving a clean scar (*fig.* 139, *b*, *b*) at the insertion. The solution of continuity begins at the epidermis, where a faint line marks the position of the future joint while the leaf is still young and vigorous; later, the line of demarcation becomes well marked, internally as well as externally; the disintegrating process advances from without inwards until it reaches the woody bundles; and the side next the stem, which is to form the surface of the scar, has a layer of cells condensed into what appears like a prolongation of the epidermis, so that when the leaf separates,' as Inman says, 'the tree does not suffer from the effect of an open wound.' Gray then, quoting Inman, adds:—'The provision for the separation being once complete, it requires little to effect it; a desiccation of one side of the leaf-stalk, by causing an effect of torsion, will readily break through the small remains of the fibro-vascular bundles; or the increased size of the coming leaf-bud will snap them; or, if these causes are not in operation, a gust of wind, a heavy shower, or even the simple weight of the lamina, will be enough to disrupt the small connexions and send the suicidal member to the grave. Such is the history of the fall of the leaf.'

(8.) *Development of Leaves.*—Leaves and all their homologous forms, such as the parts of flowers, &c. are developed laterally just below the apex of the stem by cell-division either of a group of cells as in the Phanerogamia, or of a single cell as in the Vascular Cryptogamia. A conical papilla, or (in sheathing leaves) an annular collar, is then the result of a deflection to one side of a group of these divided cells. Leaves are formed acropetally or indefinitely, the youngest always being the highest, according to the laws of Phyllotaxy. 'The papillæ from which the leaves originate are at first wholly cellular, consisting of periblem or primary meristem (see page 393), covered by a layer of dermatogen cells; after a time elongated cells are formed in the centre; and these are followed by spiral vessels, formed in a direction from the base upwards.' The first formed part of the leaf generally corresponds with its apex, or with the summit of the common petiole—i.e. the apex of a leaf is generally its *oldest* instead of its youngest part, as is the case with the stems where the apex is the growing point. (See page 396.) In leaves the apical growth soon ceases, though interstitial growth continues.

CHAPTER II.

GENERAL PHYSIOLOGY, OR LIFE OF THE WHOLE PLANT.

Having now briefly treated of the special functions of the elementary structures and of the organs of nutrition, as such structures are alone intimately concerned in maintaining the life of the plant and its various organs, we proceed to give a sketch of general physiology, or the whole plant in a state of life or action. In doing so, we shall first notice the substances required as food by plants; then proceed to consider the function of *absorption*, or that process by which food is taken up dissolved in water; and lastly, show how this fluid food is distributed through the plant, and altered in the leaves, so as to be adapted for the development of new tissues and the formation of the so-called secretions.

Section 1. FOOD OF PLANTS AND ITS SOURCES.

As plants are incapable of locomotion, being fixed to the soil or to the substance upon which they grow, or floating in water, they must obtain their food from the media by which they are surrounded, that is, as a general rule, from the soil, or from the air, or from both. In by far the majority of cases plants take up their food, both from the air by their leaves in a gaseous or vaporous state, and from the earth dissolved in water by their roots. But Epiphytes or Air Plants, as Orchids, derive their food entirely from the air by which they are surrounded (see page 122); while Parasites and Saprophytes (see page 122) essentially differ from both Epiphytes and ordinary plants in the fact that their food, instead of being derived entirely from inorganic materials, which are afterwards assimilated in their tissues, is obtained entirely or partially from the plants upon which they grow, that is, in an already assimilated condition; or, as in Saprophytes, from organic matter in a state of decay.

The materials of which plants are composed, and the constituents for the formation of which, as stated above, are generally either derived from the air or the earth, or more commonly from both, and which consequently constitute their food, form respectively their *organic* and *inorganic* compounds. In all plants there is also a varying proportion of water. The process of burning enables us conveniently to distinguish, to a great extent at least, the comparative proportions of these organic and inorganic compounds, and acquaints us with one of their distinctive peculiarities. Thus, if we take a dried plant, and burn it as perfectly as we are able, we find that the greater portion disappears in the form of gas and vapour, but a small portion of the original substance remains in the form of ash or incombustible material. The former or combustible portion is made up of *organic compounds*, that is to say, of combinations of carbon with other elements; and the latter portion of *inorganic compounds* The relative proportion of the organic and inorganic constituents varies in different plants; but, as a general rule, the former constitute from 92 to 99 parts, while the latter form from 1 to about 8 parts in every 100.

1. *The Organic Constituents and their Sources.*—The organic constituents of plants are, Carbon, Oxygen, Hydrogen, Nitrogen, and Sulphur. The first three alone form the cellulose of which the cell-walls are composed (see page 25); while the protoplasmic contents of the cell are formed of compounds of these three elements with the two other organic constituents, namely, nitrogen and sulphur. Phosphorus is also regarded as a necessary constituent of these nitrogenous cell-contents (page 27); but it belongs to the inorganic constituents.

These organic constituents are required alike by every species of plant, hence the great bulk of all plants is composed of the same elements, although the proportion of these varies to some extent in the different species, and even in different parts of the same plant.

We must now make a few remarks on each of the organic constituents, the sources from which they are derived, and the state in which they are taken up by plants.

Carbon is the most important organic constituent, forming as it does usually about one-half the weight of the entire dried substance of all plants. As carbon is a solid substance and is insoluble in water, it cannot be taken up in its simple state, for plants can only take up their food as gas or vapour, or dissolved in water. In the state of combination, however, with oxygen, it forms carbon dioxide, which is always present in the atmosphere and the soil. Carbon dioxide is also soluble to some extent in water. Hence we have no difficulty in ascertaining the source of carbon and the condition and modes in which it is absorbed by the plant; thus it is taken up essentially combined with oxygen in the form of carbon dioxide, from the air directly in a gaseous state by the leaves, and, according to some, to a small extent from the earth, dissolved in water, by the roots. Sachs, however, states: 'The fact is unquestionable that most plants which contain chlorophyll obtain the entire quantity of their carbon by the decomposition of atmospheric carbon dioxide, and require for their nutrition no other compound of carbon from without. But there are also plants which possess no chlorophyll, and in which, therefore, the means of decomposing carbon dioxide is wanting; these must absorb the carbon necessary for their constitution in the form of other compounds.'

Oxygen is, next to carbon, the most abundant organic constituent of plants; and when we consider to what an enormous extent it exists in nature, we see that there are abundant materials from which plants can obtain this necessary portion of their food. The whole of the oxygen required by plants as food appears to be taken up either combined with hydrogen in the form of water, with carbon as carbon dioxide, or in the form of oxygen salts. Some of the oxygen is therefore obtained by the roots from the soil, and some from the air by the leaves.

Hydrogen, the third organic constituent of plants, forms one-ninth by weight of water, and it is in this form that plants obtain nearly the whole of the hydrogen they require as food. Hydrogen does not exist in a free state in the atmosphere nor in the soil, and hence cannot be obtained by plants in a simple state. But in combination with nitrogen it forms ammonia, which always exists to some extent in the atmosphere and in the excretions of animals; and is also always produced during the decomposition of animal matter. Ammonia exists in a gaseous state in the atmosphere, and being freely soluble in water, the rain as it passes through the air dissolves it, and carries it down to the roots, by which organs it is taken up. The roots in like manner absorb the ammonia dissolved in water which is contained in the soil. While the larger portion of hydrogen, therefore, is taken up combined with oxygen as water, a small portion is acquired with nitrogen in the form of ammonia.

Nitrogen, the fourth organic constituent of plants, constitutes about 79 per cent. of the volume of the atmosphere, and is an important ingredient in animal tissues. It also exists in combination with oxygen as nitric acid in rain water, and in the soil as a constituent of the various nitrates and animal products there found. Whether nitrogen can be taken up by plants in a free state is at present very doubtful (see page 400), though most probably it cannot; for if all other necessary food materials be supplied to plants, but all sources of ammonia, or compounds of nitric acid, rendered inaccessible, the albuminoids and nitrogenous substances generally do not increase, although the plants may be freely exposed to the nitrogen-containing atmosphere; it is quite clear, however, that the principal form in which it is absorbed is as ammonia.

Sulphur, the only other organic constituent, is absorbed in a state of combination from the soil dissolved in water.

2. *The Inorganic Constituents or Ash, and their*

Sources.—The amount of inorganic matter found in plants, as already observed (page 411), is very much less than that of the organic. The inorganic matters are all derived from the earth in a state of solution in water; and hence we see again how important a proper supply of water is to plants. While the organic constituents are the same for all plants, *the inorganic constituents vary very much in the different kinds of plants.* The inorganic compounds of plants differ from the organic in the following particulars:—1st, they are incombustible, and hence remain as ash, when the organic compounds are dissipated by burning; and, 2nd, they are not liable to putrefaction, as is the case with them, under the influence of warmth and moisture.

The inorganic constituents of plants are as follows: —Phosphorus, Chlorine, Bromine, Iodine, Fluorine, Silicon, Potassium, Sodium, Calcium, Strontium, Magnesium, Aluminium, Manganesium, Iron, Zinc, Titanium, Lithium, Cæsium, Rubidium, Arsenic, Copper, Lead, Cobalt, Nickel, and Barium. Some of these appear to be almost universally distributed in varying proportions, but others are only very occasionally met with. The more important are Phosphorus, Chlorine, Potassium, Calcium, Magnesium, and Iron, which appear to be absolutely necessary for the nutrition of plants. These various inorganic constituents are not taken up in their simple states, but as soluble oxides, chlorides, bromides, fluorides, sulphates, phosphates, silicates, &c.

Although the amount of inorganic matter in plants is very much smaller than that of organic, still this portion, however small, is necessary to the life and vigorous development of most plants, and probably of all; although in certain Moulds no inorganic constituents have been detected.

The inorganic constituents of plants are of great importance in an agricultural point of view, and generally in growing plants for use in medicine, &c. as it is to their presence or absence, their relative quantities, and the solubility or insolubility of their compounds, in a particular soil, that it owes its fertility or otherwise, and its adaptability of growing with success one or another kind of plant.

Section 2. Life of the whole Plant, or the Plant in Action.

The various substances required by plants as food having now been considered, we have in the next place briefly to show how that food is taken up by them, distributed through their tissues, and altered and adapted for their requirements. The consideration of these matters involves a notice of the functions of vegetation. The more important facts connected with these functions have, however, already been referred to in treating of the Special Physiology of the Elementary Tissues, and of the Root, Stem, and Leaves; so that it now only remains for us in this place to give a general recapitulation of the functions of the plant, and to consider them as working together for the common benefit of the whole organism. It will be convenient to treat of these under the two heads of, 1. Absorption; and 2. Distribution of Fluid Matters through the Plant, and their Alteration in the Leaves.

1. *Absorption.*—The root, as already noticed (page 391) is the main organ by which food is taken up dissolved in water for the uses of the plant. No matter can be absorbed in an undissolved condition; and this absorptive power is owing to the superior density of the contents of the cells of the young extremities of the roots over the fluid matters surrounding them in the soil leading to the production of osmotic action through the cell-walls (see pages 384 and 391).

This imbibition of liquid by the roots is in many cases altogether independent of leaf-action, for, if the rootlets be healthy and the tissues above them filled with fluid, it will always occur; and the great force of the action in stumps cut off a little above the ground is well seen in such experiments as those of Hales (see page 419). But nevertheless, as a general rule, the amount of fluid absorbed by the roots is directly dependent upon the activity with which the other processes of vegetation are carried on, and more especially by the quantity of fluid matters transpired by the leaves; indeed, absorption is directly proportioned to transpiration in a healthy plant, for, as fluid is given off by the leaves, it is absorbed by the roots to make up for the deficiency thus produced, and therefore all stimulants to transpiration are at the same time exciters of absorption. When absorption and transpiration differ greatly in amount, the plants in which such a want of correspondence takes place become unhealthy; thus when transpiration is checked from deficiency of light, as when plants are grown in dark places, the fluids in them become excessive in amount; whilst if the atmosphere be too dry, as is the case when plants are grown in the sitting-rooms of our dwelling-houses, transpiration is greater than absorption, and hence they require to be frequently supplied with water.

FIG. 637.

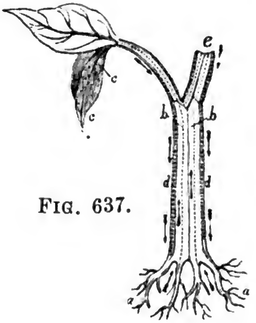


Fig. 637. Diagrammatic section of the stem of a Dicotyledon, showing the distribution of the sap. The direction is indicated by the arrows. *a*, *a*. Roots, by which the fluid matters are absorbed. *b*, *b*. The tissues by which they ascend to the leaves, *c*, *c*. *d*, *d*. Outer portions of stem and inner bark where the descent takes place. *e*. Vertical section of a branch.

2. *Distribution of Fluid Matters through the Plant, and their Alteration in the Leaves.*—The fluid matter thus absorbed by the roots (the *sap*, as it is called) is carried upwards by their tissues (*fig*. 637) to the stem,

and through its young portions to the leaves &c. (as indicated by the arrows in the figure), to be aërated and elaborated. After this it is returned to the stem, and descends probably by the inner bark and cambium layer of Dicotyledons towards the roots from which it started (page 422); and by means of the medullary rays and the general permeability of the tissues of which plants are composed, it is distributed to their different parts where new tissues are being formed, and where the so-called secretions are to be deposited. This general distribution of the fluid matters through the plant is commonly termed the *Circulation of the Sap*. The fluid as it ascends is called the *Ascending* or *Crude Sap*; and as it descends, the *Descending*, or *Elaborated Sap*. Although the term Circulation is thus commonly applied to this movement of the sap, it must be borne in mind, that the process bears no analogy to the circulation of the blood in animals; for plants have no heart or any organ of an analogous nature to propel their fluid matters, nor any system of vessels in which a flow thus produced takes place. As Professor Johnson has well put it, 'nutrient substances in the plant are not absolutely confined to any path, and may move in any direction. The fact that they chiefly follow certain channels, and move in this or that direction, is plainly dependent upon the structure and arrangement of the tissues, on the sources of nutriment, and on the seat of growth or other action.'

A. *Ascent of the Sap.*—The sap in its ascent to the leaves passes principally through the young wood-cells and vessels (page 387), and therefore in Dicotyledons, when they are of any age, through the outer portion of the wood or the *alburnum*. In such plants, also, we have but one main stream of ascending sap. In the stems of Monocotyledons and of Cormophytes the ascent also appears to take place through the unincrusted wood-cells and vessels of the fibro-vascular bundles; and hence in such plants, and more especially in Monocotyledons, we have a number of more or less distinct ascending streams. In the lower Acotyledons, as the Thallophytes, which have no stems, there is no regular course of the sap, but the fluids may be noticed flowing in all directions through their cells, and to be more especially evident in those parts which are of a lax nature.

The *cause* of the ascent of the sap is, as Herbert Spencer has well expressed it, a disturbance of equilibrium creating a demand for liquid. This ascent is produced mainly by the evaporation or transpiration going on in the leaves, but also by root-pressure (page 391), the abstraction of sap by the growing tissues, and by extravasation from the vessels by pressure. The circulation is helped by osmotic and capillary action, and also, when it occurs, by any swaying motion of the branches causing intermittent pressure on the vessels. In the winter no transpiration takes place, and the wood of the stem and roots is filled with watery matters holding starch and other insoluble substances in suspension. The fluids of the plant are therefore in a nearly quiescent state, as there are no changes then taking place to produce their distribution. When the increased heat and light of spring commence, the insoluble starch, &c., become converted into soluble dextrin, sugar, &c., development and transpiration immediately follow, and a consequent ascent of the sap. This flow continues throughout the summer months, when the causes favourable to it are in full activity; but towards the autumn, as heat and light diminish again, the force of the ascent also diminishes, and the flow of sap is again suspended in the winter months from the reasons above alluded to.

The force with which the sap ascends is probably greatest in the summer months, when heat and light are most intense, and when vegetation is consequently most active; and least in the winter. At first sight it would appear that the most rapid flow of the sap was in the spring months, at which period alone plants will give off much fluid, or bleed, as it is commonly termed, when their stems are wounded. At this period gallons of fluid will come, in some cases, in a few hours from a wounded tree before the leaves have expanded; and the fact that the leaves have not expanded is the explanation of the matter. For at this season of the year, before the leaves are expanded, the reserve materials of the tree are largely stored up in the root, and, from chemical changes there actively going on, the fluids in that part become very dense, and the consequence is that an excessive osmotic action takes place. There is far more fluid absorbed from the earth than the plant can use, and root-pressure then takes place, and this pressure forces the fluid up the stem. This is the explanation of what is called bleeding. The process does not take place at any other time of the year, for as soon as the leaves are fully developed, the fluid which is absorbed by the roots is naturally carried up the plant, and becomes transpired, and thus carried off. Hence, probably, the ascending sap has greater force in summer; but the tree does not bleed, for the leaves carry off the fluid.

In a healthy plant in a perfectly normal state, the amount of fluid absorbed by the roots, the force with which it ascends to the stem, and the amount transpired by the leaves, are directly proportionate to one another.

The force of the ascent of the sap was measured by Hales in the stem of the Vine by the apparatus represented in *fig.* 638, where *a* represents a Vine stock, to the transverse section of which is attached a bent glass tube, *d e f g*, by means of a copper cap *b*, a piece of bladder, and a lute, *c*. The bent tube being filled with mercury to the level, *e f*, at the commencement of the experiment, the force of the sap was readily calculated by the fall of the mercury in one leg of the tube *d e g*, and its corresponding rise above *f* in the other leg. In this way he found, that in one experiment the force of the ascent was sufficient to support a column of mercury $32\frac{1}{2}$ inches in height. Brucke, however, in his experiments on the force of the ascent of the sap in the spring in the Vine, found that it was only equal to the support of a column of mercury $17\frac{1}{2}$ inches high. Hales' experiment is, however, a measure of the force of absorption by the root (*root-pressure*) rather than of the ascent of the sap (see pages 391 and 419).

FIG. 638.

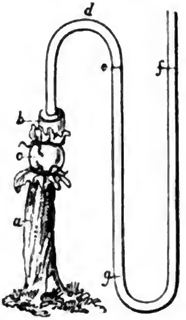


Fig. 638. Apparatus employed by Hales to show the force of the ascent of the sap. *a.* Cut vine stock. *b.* A copper cap, which is secured to the stock by means of a piece of bladder and lute, *c*; *d e f g.* bent glass tube attached to the copper cap, and containing mercury, the level of which, at the commencement of the experiment, is marked by *e f*, and at the conclusion in one leg of the tube, by *g*; and hence the mercury in the other leg must have risen in a corresponding degree to its depression in the former.

As the fluid rises in the stem it is of a watery nature, and contains dissolved in it the various inorganic matters in the same state nearly in which they were absorbed by the roots. It also contains a variable amount of organic products, which it has dissolved in its course upwards. (A recent analysis by Attfield of the spring sap from a 'bleeding' White Birch tree, showed that it 'consisted of 99 parts of pure water with 1 part of dissolved solid matter; eleven-twelfths of the latter was sugar.') But when it reaches the leaves it is entirely unfitted for the requirements of the plant, and is hence called Crude Sap. In the leaves and other green parts it undergoes certain stages, by which it becomes altered in several particulars, and is then adapted for the uses of the plant. In this state it is termed Elaborated Sap.

B. *Changes of the Crude Sap in the Leaves.*—The changes which the crude sap undergoes in the leaves and other green parts by the action of light and air have been already alluded to in treating of the Functions of Leaves; it will be here, therefore, only necessary to state in what those changes essentially consist. They are:—1st. The transpiration of the superfluous fluid of the crude sap in the form of watery vapour, by which it becomes thickened. 2nd. The taking up from the air of oxygen and giving off of carbon dioxide, small quantities of water being probably formed at the same time, to which the term *Respiration* is now applied. The oxygen thus taken up in respiration is necessary to the vitality of the protoplasm, as also for the oxidation of nutrient matters during the process of metastasis, &c. Respiration is most evident during the night, for the large quantity of oxygen given off during the day in the process of assimilation obscures the former change. 3rd. The absorption and decomposition of carbon dioxide, by which carbon—that most important constituent of plants—is added to the crude sap, whilst oxygen is evolved, carbohydrates being at the same time produced. To this the term *Assimilation* is applied. The carbohydrates so formed may be starch, fat, or cane sugar, but more especially starch (page 403). A further process is found to take place in some of the assimilated substances; thus they may change their position, passing from the cells in which they were formed to others, generally also undergoing at the same time a change in their chemical composition; which combined changes are termed *metabolism* or *metastasis*. The differences between *assimilation* and *metastasis* may be seen in the Potato, where by the former process starch is formed in the chlorophyll-bearing leaves, which in its turn is converted into a glucoside in the stem and branches, and back again into starch in the tubers by metastasis. The crude sap being thus converted into elaborated sap, then contains in itself the various nitrogenous and non-nitrogenous matters which are required for the development of new tissues and the formation of other organic products, which are commonly termed secretions.

Those organic matters which are necessary for development or growth are termed *constructive materials*, whereas those which are formed by metastasis and which are not constructive—may be divided into two groups—

1. *Degradation products*, such as wood and cork, which can never be reconverted into constructive materials, though of the greatest use to the plant in giving mechanical support; protecting the internal living tissues from frost; enabling plants to withstand the scorching heat of the sun; and in other ways. Many gums, as tragacanth, gum arabic, and others; and gum resins, as myrrh and bdellium, are also formed from the cell-walls, &c., of different plants, and are, therefore, other examples of such products.

2. *Secondary products of metastasis*, some of which, as sweet secretions, &c., are necessary for the perpetuation of the species, by attracting insects, and so furthering fertilisation; while others—as ethereal oils, resins, colouring matters, and many acids and alkaloids—appear to be of no further use to the plant.

C. *Descent of the Sap.*—After the crude sap has been transformed in the manner already described, it passes from the leaves to the stem, probably to the inner bark, and cambium layer of Dicotyledons; and apparently to the parenchymatous tissues generally of the stems of Monocotyledons and of Cormophytes. It then descends in the stems of the several kinds of plants as far as the root, and in its course affords materials for the development of new tissues and the production of flowers and fruit; and at the same time undergoes further changes owing to metastasis, and deposits its various secretions, &c. (page 421). Hoffmann, in his experiments upon Ferns, however, could not find any path by which the elaborated juices descended in the stem.

That the elaborated sap in Dicotyledons descends through the inner bark and cambium layer is commonly believed, and several facts seem to support this belief. Thus, the formation of wood is obviously from above downwards, for when a ligature is tied tightly round the bark of an Exogenous stem, or more especially if a ring of bark be removed, no new wood is produced below the ligature or ring, while there will be an increased development above it; or roots will be produced there. Again, it is well known, that by removing a ring of bark from a fruit tree, a larger quantity of fruit may be temporarily obtained from that tree, owing to the greater amount of nutritive matter which then becomes available for the use of the reproductive organs. Another circumstance which appears to show the line of descent of the nutritive matter, is the fact, that if the cortical parts of the stems or branches of a Potato plant be peeled off, the formation of tubers is prevented. It appears that the descending sap supplies the material for the formation of new wood in the fibro-vascular layers. Its course, as well as by the laticiferous vessels, sieve-tubes, &c., is also lateral, for in autumn starch grains are found in the medullary rays between the wedges of developed wood; and where growth is going on, even an upward direction may be assumed. Herbert Spencer, however, argues that the retrograde motion of the sap is through the same channels—chiefly, as he believes, the vessels of the newest wood—by which it passed up, He considers that this descent takes place in response to a demand for liquid by the stem and roots when evaporation from the leaves is at a standstill, as at night. As far as the leaf-petioles are concerned, the back current must be along much the same tissues as the upward flow; but probably the liber-cells of the petiole are the main channel, and these are directly continuous with the inner bark of the stem.

The opinions of observers vary much as to the offices of the different parts of plants; for instance, Mulder considers that all nitrogenous matters are not only absorbed by the roots, but also assimilated by them at once, while carbon is fixed by the green parts; so that a constant interchange must take place between the leaves and roots. Other authors, again, believe that the leaves form all the organic substances. While Sachs says: 'By the parenchyma of the fundamental tissue, which always has an acid reaction, are conveyed the carbo-hydrates and oils; by the soft bast the mucilaginous albuminoids, which have an alkaline reaction.'

CHAPTER III.

PHYSIOLOGY OF THE ORGANS OF REPRODUCTION.

Having now alluded to the special functions of the elementary structures, and of the organs of nutrition, and also to the general physiology or life of the whole plant, we proceed in the next place to treat of the functions of the organs of reproduction.

1. Functions of Bracts and Floral Envelopes.—One of the principal offices performed by these organs is, to protect the young and tender parts placed within them from injury. When green, as is commonly the case with the bracts and sepals, their colour is due to the presence of chlorophyll in their component cells, and they then perform the same functions as ordinary leaves. But when of other colours than green, as is usual with the petals, and occasionally with the bracts and sepals, they appear to have, in conjunction with the thalamus, a special function to perform; which consists in the production of a saccharine substance from the amylaceous matter stored up in them. This saccharine matter is designed more especially for the nourishment of the essential organs of reproduction. In fact a similar change takes place in the process of flowering to that which occurs in germination, where the amylaceous matters are in like manner converted into those of a saccharine nature.

During this conversion of amylaceous into saccharine matters, oxygen is absorbed in great quantities from the atmosphere, and carbon dioxide given off in a corresponding degree. Hence, the action of the parts of the flower which are of other colours than green, upon the surrounding air under the influence of solar light, differs from that of the leaves and other green organs.

The combination which under the above circumstances takes place between the carbon of the flower and the oxygen of the air, is also attended by an evolution of heat, which indeed is always the case where active chemical combination is going on.

Colour of Flowers.—All the colours of flowers otherwise than green depend on bodies the nature of which is very imperfectly known, though spectroscopic analysis has done something towards grouping them into series. The changes in colour which many corollas undergo are supposed to depend on the oxidation of these bodies. Most of the Boraginaceæ pass from pink to blue, from their first expansion till they are fully open; the garden Convolvulus changes from pink to a fine purple in the same period. Cultivation will effect great changes in this respect, but there is a limit to its influence. Thus the Dahlia and Tulip are naturally yellow, and under cultivation may be made to assume all shades of red, orange, and white, but no tint of blue; Geraniums and the Hydrangea will take on various shades of blue, purple, red, and white, but never a yellow. These facts led De Candolle to divide flowers in this aspect into two series—a *xanthic* which has yellow for its base, and a *cyanic* which has blue—either of which can be made red or white, but will not assume the basic colour of the other. There seem to be a few exceptions to this rule; e.g. *Myosotis versicolor* changes from yellow in the bud to blue in the open corolla, and the Hyacinth is not unfrequently a pale yellow.

Development of the Floral Envelopes.—The manner in which the floral envelopes are developed may be shortly summed up as follows:—

They are subject to the same laws of development as the usual foliage leaves, and make their first appearance as little cellular processes, which grow by additions to their base or points of attachment to the axis.

The calyx is commonly developed before the corolla.

When a calyx is polysepalous, or a corolla polypetalous, the component sepals or petals make their first appearance in the form of little distinct papillæ or tumours, the number of which corresponds to the separate parts of the future calyx or corolla.

When a calyx is monosepalous, or a corolla monopetalous, the first appearance of these organs is in the form of a little ring, which ultimately becomes the tube of the calyx or corolla, as the case may be. When these present lobes or teeth, as they more commonly do, these arise as little projections on the top of the ring, the number of which corresponds to the future divisions of the calyx or corolla.

All irregular calyces or corollas are regular at their first formation, the cellular papillæ from which they arise being all equal in size; hence all irregularity is produced by unequal subsequent growth.

2. FUNCTIONS OF THE ESSENTIAL ORGANS OF REPRODUCTION.—*Sexuality of Plants.*—The sexuality of plants has now been proved, and, as we have repeatedly stated, the stamens of flowering plants constitute the male apparatus, and the carpels the female. Again, while the presence of distinct sexes may thus be shown in flowering plants, both of which are necessary for the formation of perfect seed, by far the greater number of flowerless plants, in like manner, as we have seen, possess certain organs the functions of which are undoubtedly sexual.

We have already, as fully as our space will admit, described the structure of the reproductive organs of both Phanerogamous and Cryptogamous plants; we now proceed to give a general summary of the more important conclusions which have been arrived at as regards the process of reproduction in the different divisions of plants, commencing with the Cryptogamia.

(1.) REPRODUCTION OF CRYPTOGAMOUS OR ACOTYLEDONOUS PLANTS.—A. *Reproduction of Thallophytes.*—The sexuality of all Thallophytes has not been absolutely proved, but only concluded from analogy. Sexes have been clearly shown to exist in Algæ, Characeæ, Fungi, and Lichens. The process of reproduction in the Algæ, Fungi, and Lichens has already been sufficiently noticed (see pages 350–365, and 368–375); but the Characeæ require a little more explanation.

Reproduction of Characeæ or Charas.—In these plants we have two kinds of reproductive organs, called, respectively, the *globule* (*figs.* 613, *a*, and 615), and the *nucule* (*figs.* 613, *s*, 616, and 617): the former is regarded as the *male organ*, and the latter as the *female.* Fecundation takes place by the passage of the spiral spermatozoids of the globule (*fig.* 614) down the canal which extends from the apex of the nucule (*figs.* 616, *a*, and 617) to the central cell of the same structure, which then becomes fertilised. No free spore is, however, produced, but the nucule drops off, and after a certain period germinates, though the sexual leaf-forming

FIG. 639.

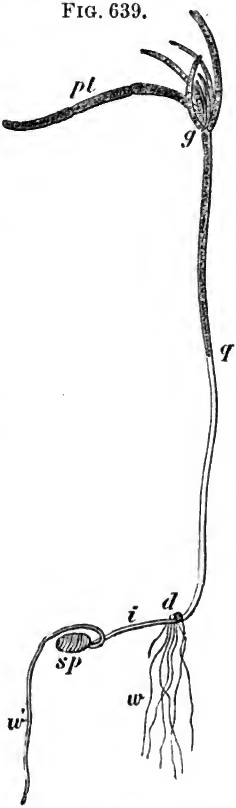


Fig. 639. Pro-embryo of *Chara fragilis. sp.* Germinating spore. *i d q pl.* The pro-embryo. At *d* are the rhizoids, *w. w'.* Primary root. *g.* First leaves of the second generation, or *Chara* proper. After Pringsheim.

plant is not directly developed, but is preceded by a *pro-embryo*, which has, however, only a limited growth, and from it are produced at one part the rhizoids (*rootlets*), and further on, as a sort of lateral branch, the *Chara* proper (*fig.* 639, *g*). In *Nitella* the production of a pro-embryo has not been definitely observed, and here the new plant seems to be formed at once from the detached nucule.

B. *Reproduction of Cormophytes.*—Of the sexual nature of the plants in most orders of this sub-division of the Cryptogamia there can be no doubt. The sexual organs in all are also of an analogous character, and are of two kinds, one termed an *antheridium*, which contains spirally wound ciliated antherozoids or spermatozoids, and is regarded as the male organ; and the other, called an *archegonium* or *pistillidium*, containing an embryonal cell or germ-cell, which is the female organ. Fecundation is supposed to be effected by the contact of a spermatozoid with the germ-cell. We have already described the structure of the reproductive organs of Cormophytes (pages 333–350), both before and after fertilisation; it will only be necessary, therefore, in the present place, to say a few words upon the mode in which fertilisation is supposed to take place in the different natural orders included in this division of the Cryptogamia, which are here, however, arranged in the inverse order to that in which they were formerly described.

(1.) *Hepaticaceæ or Liverworts.*—The general nature of the reproductive organs, and method of reproduction have already been described, and may be summed up as follows:—The two reproductive organs of this order, which closely resemble those of the Mosses, are termed *antheridia* (*fig.* 590) and *archegonia* or *pistillidia* (*fig.* 592), the former representing the male sex, and the latter the female. When the antheridium bursts (*fig.* 590), it discharges a number of small cells, which also burst, and each emits a very small 2-ciliated spiral spermatozoid. These spermatozoids are supposed to pass down the canal of the archegonium (*fig.* 592) to the germ-cell which is situated at its bottom, which thus becomes fertilised. This cell after fertilisation undergoes various important changes, as already noticed (see page 348), and ultimately becomes a sporangium, enclosing spores and *elaters* (*fig.* 593), which are elongated, spirally thickened cells, whose office is to assist in disseminating the spores when the valves of the sporangia open. When these spores germinate, they frequently produce (page 350) a sort of confervoid structure or mycelium (*prothallium*), which in its after-development resembles the like structure of Mosses.

(2.) *Musci or Mosses.*—The reproductive organs of this order consist of *antheridia* (*fig.* 580) and *archegonia* (*fig.* 581), which closely resemble the same structures in the Hepaticaceæ. Fertilisation takes place in a similar manner (see above), and the changes which take place after fertilisation in the germ-cell which ultimately forms a sporangium containing spores, but not elaters (*fig.* 588), have already been described. (See page 343.)

In germination, the spores at first form a green cellular branched mass or prothallium, resembling a Conferva, which is sometimes termed the *protonema.* Upon the threads of this structure (*fig.* 640), buds (*a*) are ultimately produced, which grow up into leafy stems (*b*), upon which the antheridia and archegonia are afterwards developed.

FIG. 640.

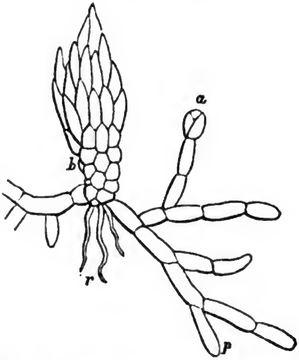


Fig. 640. *Prothallium* or *protonema* of a Moss (*Funaria hygrometrica*). *p.* Protonema *a.* Bud. *b.* Young leafy stem. *r.* Rootlets.

(3.) *Lycopodiaceæ or Club-Mosses.*—The two reproductive organs of this order are termed *macrosporangia*, *oosporangia* or *oophoridia* (*fig.* 579), which represent the female; and *microsporangia*, *pollen sporangia*, or *antheridia* (*fig.* 578), which are regarded as male organs. The contents of the microsporangia are called *small spores* (*microspores*), which break up into two sets of cells—one of which remains inactive, and probably represents an abortive prothallium; while the other develops the antherozoids (*fig.* 641, *c*). In the macrosporangia are formed *large spores*, *macrospores*, or *megaspores* (*fig.* 579). In *Lycopodium*, however, only microspores have been detected.

FIG. 641.

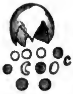


FIG. 642.

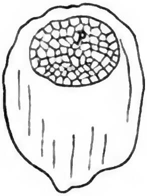


FIG. 643.

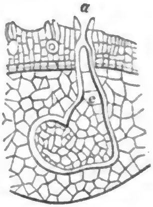


Fig. 641. *Small spore*, *pollen spore*, or *microspore*, of a species of *Selaginella*, bursting and discharging small sperm-cells, *c*, in which antherozoids are contained.——*Fig.* 642. *Large spore*, *macrospore*, or *megaspore*, of a species of *Selaginella*. The outer coat of the spore has been removed to show the entire inner coat, with the young prothallium, *p*, at the upper end.——*Fig.* 643. Vertical section of a portion of the prothallium of the above in a more advanced state, showing the archegonia. *a*. Archegonium, in which the pseudo-embryo, *e*, has been developed from the germ-cell it contained, by contact with the antherozoids. This embryo, by the growth of the suspensor, is forced downwards and imbedded in the upper part of the cellular mass of the spore-sac.

It is not till some months after being sown that the spores commence to germinate, nor are the antherozoids produced till a nearly equal period has elapsed. In germination, the spore (*macrospore*) produces a very small prothallium (*fig.* 642, *p*), on which archegonia (*fig.* 643, *a*) are subsequently developed. Each archegonium (*fig.* 643, *a*) consists of an intercellular canal leading into a sac below, which contains a single germ-cell. Fertilisation is considered to take place by the ciliated antherozoids contained in the microspores (*fig.* 641, *c*), passing down the canal of the archegonium, and coming into contact with the germ-cell. This cell then grows by cell-division, and forms a *pseudo-embryo* (*fig.* 643, *e*), and ultimately produces a new leafy sporangiferous stem.

(4.) *Marsileaceæ or Pepperworts.*—The two reproductive organs of this order are generally distinguished as *antheridia* (*figs.* 573 and 575, *a*) and *pistillidia*, *macrosporangia*, or *sporangia* (*fig.* 575, *b*). These two structures are either contained in separate sacs, as in *Salvinia* (*fig.* 575), or in the same, as in *Marsilea* (*fig.* 572). The antheridia contain a number of small cells, called generally *pollen spores*, *microspores*, or *small spores* (*fig.* 644), which ultimately produce antherozoids remarkable for their length and delicacy (*fig.* 644). The pistillidia or macrosporangia contain commonly but one spore, called an *ovulary spore*, *large*

FIG. 644.

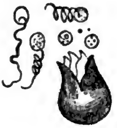


FIG. 645.

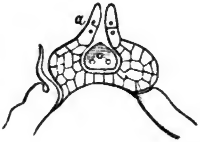


Fig. 644. *Pollen spore*, *small spore*, or *microspore*, of Pill-wort (*Pilularia globulifera*), bursting and discharging small cells, enclosing antherozoids. Some of the latter may be observed to have escaped by the rupture of the small cells in which they were contained.——*Fig.* 645. Vertical section of the prothallium of the above, which is formed, as in the Lycopodiaceæ, in the interior of the *large spore* or *macrospore*. Only one archegonium, *a*, is here produced in the centre. The archegonium consists of an intercellular canal, leading into a sac below, in which may be seen a solitary *germ* or *embryonal cell.*

spore, *macrospore* or *megaspore*. In their organs of fructification the plants of this order closely resemble the Lycopodiaceæ. Like the Lycopodiaceæ the large spores also produce a small prothallium confluent with them, in which subsequently only a single archegonium generally, as in *Pilularia* and *Marsilea*, appears (*fig.* 645, *a*), although in *Salvinia* several archegonia are formed. Impregnation takes place by the contact of the antherozoids with the germ-cell of the archegonium, which immediately develops, and forms a pseudo-embryo bearing a great apparent similarity to the embryo of a mocotyledonous plant, from which a leafy stem bearing fructification is ultimately produced.

(5.) *Equisetaceæ* or *Horsetails*. And

(6.) *Filices or Ferns*.—The mode of reproduction of the plants of these two orders is essentially the same, and we shall accordingly allude to them together. As already fully described (see pages 333–338), their leafy structures bear sporangia or capsules in which the spores are enclosed (*figs.* 562–565, and 569–571). There is, however, but one kind of spore.

In germination, which has also been noticed (pages 335 and 338), these spores ultimately form a thin, flat, green parenchymatous expansion (*fig.* 566). Upon the under surface of this structure we have soon formed, in the Filices, both *antheridia* and *archegonia*; but in most of the Equisetaceæ, the antheridia and archegonia have only been found on separate prothalli, and hence these plants would appear to be diœcious. The antheridia (*fig.* 567) contain a number of minute cells called *sperm-cells* (*se*), each of which contains a spirally wound ciliated antherozoid (*sp*). The *archegonium* (*fig.* 568) is a little cellular papilla, having a central canal, which when mature is open. At the bottom of the canal is a cell called the *embryo-sac*, in which a *germ* or *embryo-cell* is developed. This so-called embryo-cell is, however, simply a germinal corpuscle till after fertilisation; that is, a free primordial cell, or mass of protoplasm, without an external wall of cellulose.

FIG. 646.

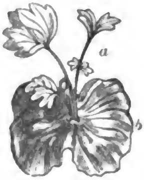


Fig. 646. *a.* Young sporangiferous plant of a species of Fern (*Pteris*) arising from the fertilised germ-cell in the archegonium of the prothallium, *b.*

When mature, the upper part of the antheridium separates from the lower, something like the lid of a box; the sperm-cells then escape, become ruptured, and emit their contained spermatozoids. These spermatozoids make their way down the canal of the archegonium to the embryo-sac, by which the contained germ-cell or germinal corpuscle, is fertilised. This germ-cell then develops a pseudo-embryo, which soon possesses rudimentary leaves and roots (*fig.* 646), and ultimately produces a plant with fronds bearing sporangia or capsules, which resembles the parent from which the spore was originally obtained. The Ferns and Horsetails are thus seen to exhibit two stages of existence, as already explained at pages 337 and 338. Hence Ferns and Horsetails exhibit what has been termed *alternation of generations.*

(2.) REPRODUCTION OF PHANEROGAMOUS OR COTYLEDONOUS PLANTS.—In all the plants belonging to this division of the Vegetable Kingdom the *male apparatus* is represented by one or more stamens, each of which essentially consists of an anther enclosing *pollen* (*fig.* 23, *p*); and the *female*, by one or more carpels, in (*fig.* 28) or upon (*fig.* 13) which, one or more ovules are formed. When the ovules are contained in an ovary (*fig.* 28), the plants to which they belong are called *angiospermous*; but when they are only placed upon metamorphosed leaves or open carpels (*fig.* 13), the plants are said to be *gymnospermous.* In the plants of both these divisions of the Vegetable Kingdom the ovules by the action of the pollen are developed into perfect seeds whilst connected with their parent, the distinguishing character of a seed being the presence of a rudimentary plant called the embryo. The modes in which reproduction takes place, and the after development of the embryo, differ in several important particulars in Gymnospermous and Angiospermous plants; hence it is necessary to describe them separately.

A. *Reproduction of Gymnospermia.* — We have already given a general description of the pollen and ovules of Phanerogamous plants, but as these structures present certain differences in the Gymnospermia from those found in the Angiospermia, it will be necessary for us to allude to such peculiarities before describing the actual process of reproduction.

The pollen of the Angiospermous division of the Phanerogamia generally consists, as we have seen (pages 246–248), of a cell containing a matter called the *fovilla*, and having a wall which is usually composed of two coats, the outer being termed the *extine*, which possesses one or more pores or slits (*fig.* 407, *f*), or both; and the inner, called the *intine*, which is destitute of any pores or slits, and consequently forms a completely closed membrane. Each pollen-grain of the Angiospermia is thus seen to be a simple cell. In the Gymnospermia, on the contrary, the pollen-grains are not simple cells, but they contain other minute daughter-cells which adhere to the inside of the internal membrane close to the point where the external membrane presents a slit, and from one of which the pollen-tube is developed.

The ovules of the Gymnospermia, excluding those of the Gnetaceæ, consist of a nucleus (*fig.* 647, *a*), enclosed by a single coat, and with a large micropyle, *m*. Before the contact of the pollen with the micropyle, the primary embryo-sac, *b*, is developed in the nucleus. This embryo-sac is at first very small (*fig.* 647, *b*), but gradually enlarges (*fig.* 648, *a*), and after a long period becomes filled by free cell-formation with delicate cells, called endosperm cells (*fig.* 648, *b*), which disappear very soon, and are replaced later on by a fresh development. The following account of the subsequent development of the ovule, and the mode by which it is fertilised, is taken from Henfrey, and is founded upon Hofmeister's investigations.

'In the upper part of the mass of the last formed endosperm (*fig.* 648, *b*), from five to eight cells are found to expand more than the rest, forming *secondary embryo-sacs* or *corpuscula*. These are not formed in the superficial cells of *b*, but from cells of the second layer, so that each is separated from the membrane of the primary embryo-sac by one cell (*fig.* 649, A). These *corpuscula*, as they were called by Robert Brown, their discoverer, are very much like the archegonia in the internal prothallium structure of *Selaginella*. After a time the secondary embryo-sacs divide into an upper or *neck-cell*, and a lower or central cell, *egg* or *oosphere*. The neck-cell speedily divides and subdivides, to form the rosette, which surmounts the central cell. In the upper part of this latter is then formed, from subdivision of the nucleus, a very delicate cell, which is called the *canal-cell*. The mature corpuscle therefore consists of

FIG. 647.

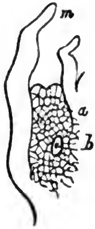


FIG. 648.

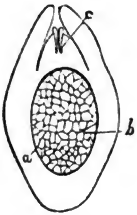


Fig. 647. Vertical section of the young unimpregnated ovule of a species of *Pinus*. *a*. Nucleus containing a small primary embryo-sac, *b*. *m*. Micropyle, which is here very large. *Fig.* 648. Vertical section of an older ovule of the same. *a*. Enlarged primary embryo-sac. *b*. Endospermal cells within the embryo-sac. *c* Pollen-tubes penetrating the apex of the nucleus.

a large central cell surmounted by a rosette of small cells placed immediately beneath the wall of the primary embryo-sac, or separated from it by a funnel-shaped space' (*fig.* 649, B).

The process of fertilisation takes place, as follows: After the contact of the pollen with the micropyle of the ovule, the pollen-tube, after remaining passive for a

FIG. 649.

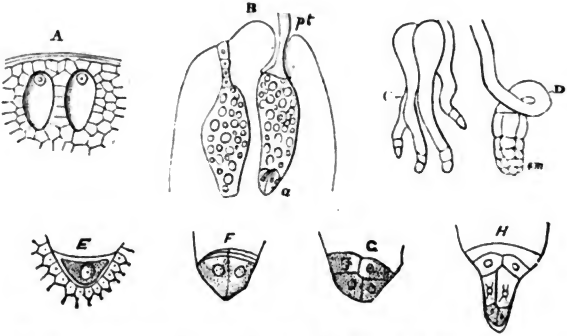


Fig. 649. Development of the embryo in a species of *Pinus.* After Henfrey. A. Upper part of the embryo-sac, with two secondary embryo-sacs, corpuscula, or archegonia. B. The same, more advanced. *pt.* Pollen-tube in the canal leading down to the corpuscula. *a.* Germinal corpuscles at the base of the secondary embryo-sac. E, F, G. Successive stages of development of germinal corpuscles, *a* in B. C. Four cellular filaments or *suspensors* which are developed from the germinal corpuscles after impregnation; at H, is shown an earlier stage. D. One of these suspensors, with the embryo (*em*) at its apex.

variable space of time, takes an active growth, traverses the endosperm, and arrives at the embryo-sac by the time the corpuscles are developed (*fig.* 649, *pt*). It penetrates the wall of the embryo-sac, enters into and dilates the funnel-shaped space just mentioned, passes down between the cells of the rosette, pushing them on one side (Taxaceæ, Cupresseæ), or causing their absorption and disappearance (Abieteæ) as well as that of the *canal-cell*, and finally penetrates into the cavity of the canal-cell. The changes which take place in this latter are, according to Strasburger, these:—disappearance of the original nucleus, and formation of four to eight new nuclei by condensation of the protoplasm and subsequent secretion of a cellulose wall around them. In this way four to eight new cells are formed by free cell-formation in the central cell after fertilisation; these new cells divide so as to form cellular filaments, which break out through the bottom of the endosperm into the substance of the nucleus (*fig*. 649, C). At the ends of these filaments cell-division again occurs (*fig*. 649, D); and from the apex of one of these *suspensors* or *pro-embryos* is developed, by repeated cell-division in various directions, the embryo (D, *em*). At one stage (in *Thuja*) a single apical cell, the terminal one of a group of five, from which ultimately all the tissues of the embryo are formed, recalls the single apical cell of the Cryptogamia, but it is soon lost by subdivision. As there are several corpuscles, and each produces four suspensors, a large number of rudimentary embryos are developed; but usually only one of all these rudiments is perfected.

'That embryo which is fully developed gradually increases in size, and most of the structures above described disappear, so that the ripe seed exhibits a single embryo imbedded in a mass of endosperm or albumen, the latter originating apparently from the nucleus of the ovule. The radicle is covered by a *pileorhiza*, which is ultimately blended with the substance of the endosperm.'

B. *Reproduction of Angiospermia.*—The structure of the pollen-cells of the Angiospermia has been already described, and need not therefore be further alluded to.

The ovule has also been particularly noticed, and we shall now only recapitulate its component parts at the time when the pollen is discharged from the anthers—that is, just before impregnation takes place. It then consists of a cellular nucleus (*fig*. 650, *n*), enclosed generally in two coats—an outer the *primine*, and an inner the *secundine*, as in the present figure. But sometimes there is but one coat (*fig.* 522), and in rare cases the nucleus is naked, or devoid of any coat (*fig.* 520).

These coats completely invest the nucleus except at the apex, where a small opening or canal is left, termed the micropyle (*fig.* 650, *m*). In the interior of the nucleus, but of various sizes in proportion to it, the embryo-sac (*fig.* 650, *s*) is commonly seen. The embryo-sac contains at first a more or less abundant quantity of protoplasm; in this nuclei afterwards appear (*fig.* 651, *s*), which, by the process of free cell-development, form a corresponding number of cells (usually two), which are commonly termed *germinal vesicles* (*figs.* 651, *c*, and 652, *b*). The vesicles are situated at or near the summit of the embryo-sac. As already stated, however, (page 305), these germinal structures are now almost invariably regarded as not perfect cells with a cellulose coat before impregnation, but merely corpuscles of nucleated protoplasm, or primordial cells. At the base

FIG. 650.

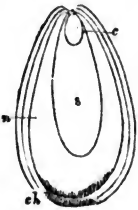


FIG. 651.

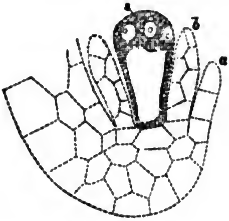


FIG. 652.

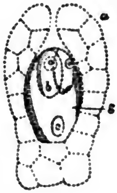


Fig 650. Vertical section of the orthotropous ovule of a species of *Polygonum*. *ch*. Chalaza. *n*. Nucleus invested by two coats. *m*. Micropyle. *s*. Embryo-sac. *c*. Germinal vesicle or oosphere. ——*Fig*. 651. The ovule, some time before fertilisation. *a*. The outer coat. *b*. The inner coat. *s*. The embryo-sac, with three nuclei at the upper end.——*Fig*. 652. The internal parts of the ovule a short time before fertilisation. *a*. Inner coat of the ovule. *s*. Embryo-sac. *b*. Germinal vesicles. *c*. Antipodal cell. After Hofmeister.

of the embryo-sac, as already described (page 306), there are also, before fertilisation, two or more nucleated cells termed *antipodal cells* (*fig.* 652, *c*).

When the pollen in the process of *pollination* falls upon the stigma (*fig.* 654, *b*, *a*) (the tissue of which at this period, as well as that forming the conducting tissue of the style and neighbouring parts, secretes a peculiar viscid fluid as described at page 254), its intine protrudes through one or more of the pores or slits of the extine (*fig.* 653, A, B) in the form of a delicate tube, which penetrates through the cells of the stigma, by the viscid secretion of which it is nourished. In most plants but one pollen-tube is emitted by each pollen-cell (*figs.* 653, A and B), but the number varies, and, according to some observers, is sometimes twenty

FIG. 653.

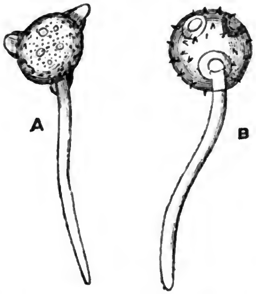


FIG. 654.

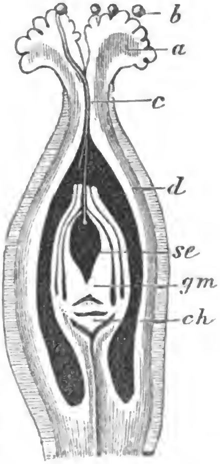


Fig. 653. A. Pollen-cell of *Dipsacus Fullonum.* B. Pollen-cell of *Cucurbita.* Each pollen-cell is putting out a single pollen-tube. After Thomé.——*Fig.* 654. Longitudinal vertical section through uniovular ovary of *Polygonum Convolvulus.* *a.* Stigma. *b.* Pollen-cells. *c.* Pollen-tube. *d.* Wall of ovary. *gm.* Erect orthotropous ovule. *se.* Its embryo-sac. *ch.* Chalaza.—N.B. Two of the pollen-tubes have penetrated the conducting tissue of the style, and one of which has entered the micropyle of the ovule, the other not. After Thomé.

or more. The pollen-tube continues to elongate by growth at its apex, and passes down through the conducting tissue of the style (*fig.* 654, *c*) when this exists, or directly into the ovary when the style is absent.

These tubes vary in length; they are frequently many inches, and are extremely thin. They are commonly unicellular, and have therefore but one cavity; but, according to Professor Martin Duncan, in *Tigridia*, and all other Monocotyledonous plants with long styles which he examined, they are composed of several elongated cells placed end to end, and hence having as many cavities as cells. The time required for the development of these tubes also varies in different pollen-cells; thus, sometimes they are developed almost immediately the pollen comes into contact with the stigma; while in other cases, many hours are required for the purpose. The pollen-tubes also occupy a varying time in traversing the canal of the style—that is, from a few hours to some weeks, or even months. When the pollen-tubes have penetrated the stigmatic tissue, the secretion of the latter ceases and the stigma dries up. The upper part of the pollen-tubes also withers above, as growth takes place below.

The pollen-tubes having reached the ovary are distributed to the placenta or placentas, and then come ultimately in contact with the ovule or ovules. One (or sometimes two) of these pollen-tubes enters into the micropyle of each of the ovules (*figs.* 654, *c*, 655, *t*, and 656, *t*). and thus reaches the nucleus and embryo-sac. When it arrives at the latter it is generally somewhat enlarged (*fig.* 656, *t*), and adheres firmly to it at or near its apex, and the embryo-sac is frequently introverted to a slight extent at the point of contact with the pollen-tube (*fig.* 655). As soon as the contact of the pollen-tube with the embryo-sac is effected, a kind of conjugation or osmotic action between the contents of the two takes place, the result of which is the development of one, or rarely two, as in *Orchis* and *Citrus*, or more, of the so-called germinal vesicles or oospheres, into embryos.

The germinal vesicle or oosphere, in its development into an embryo, first becomes coated with a cellulose membrane, and then generally divides in a transverse manner into two cells (*fig.* 656, *e*); the upper of which by elongating, and frequently by further division, forms the *pro-embryo* or *suspensor* (*fig.* 655, *s*), by which the lower or true embryonal cell is suspended from the apex of the embryo-sac. This lower cell (*fig.* 655, *r*), soon divides transversely and lengthwise into a more or less rounded mass of cells, from which the embryo, whether monocotyledonous or dicotyledonous, is ultimately produced. The changes which take place in the

FIG. 655.

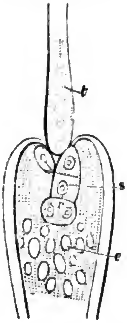


FIG. 656.

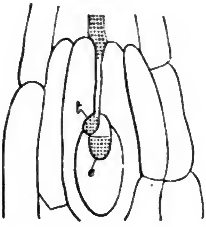


Fig. 655. Vertical section of the ovule of a species of *Œnothera*. *t.* Enlarged end of pollen-tube containing fovilla, which has entered the micropyle, and is seen pressing inwards the apex of the embryo-sac. *s*, *r*. Impregnated germinal vesicle or oosphere, which already begins to exhibit two parts: one, the upper, forming a suspensor, *s*, and another, below, *r*, a globular body, which ultimately becomes the embryo. *e*. Endosperm cells or albumen. ——*Fig.* 656. Section of the ovule of a species of *Orchis*. *t*. Enlarged end of the pollen-tube which has passed through the micropyle, and is closely applied to the embryo-sac, the upper side of which it has pushed inwards. *e*. Germinal vesicle or oosphere in the interior of the embryo-sac in an impregnated state, and dividing into two portions, the lower of which is the rudimentary embryo, and the upper forms a suspensor.

ovule during the development of the embryo, and the subsequent growth of the latter, have been already alluded to when treating of the seed.

Darwin has shown that, in numerous plants, *crossing* is necessary for a completely fertile union of the sexes; that is, that the ovules of one flower must be fertilised by pollen from another of the same species. This may be effected in many ways; e.g. by the wind in diœcious plants, or frequently by the unconscious agency of insects, as in the Orchidaceæ, where the various modifications of structure to insure cross-fertilisation by this latter means are strikingly beautiful. It seems not unlikely that further investigations will prove that self-fertilisation is exceptional in plants; certainly occasional crossing seems to be necessary.

Dimorphic (page 243) or *heterostyled* species are those which possess two forms of both sorts of sexual organs, as species of *Primula*, *Oxalis*, and *Pulmonaria*, which have both long and short stamens, and long and short styles. The long stamens are associated with the short styles and *vice versâ*, in the flowers; and Darwin has proved, by experiment, that, for the complete fertilisation of either kind of pistil, it is necessary that pollen from the stamens of corresponding length, and therefore from a different flower, be employed. *Lythrum Salicaria* is trimorphic—i.e. has styles and stamens of three different lengths—and similar laws have been observed to prevail in its fertilisation. *Legitimate* fertilisation is the impregnation of the style of one flower by the pollen from a stamen of equal length with itself, but belonging to another flower; while the fertilisation of a pistil by pollen from a stamen of different length is termed *illegitimate.*

Hybridisation, Hybridation, or the Production of Hybrids in Plants.—If the pollen of one species is applied to the stigma of another species of the same genus, should impregnation take place, the seeds thus produced will give rise to offspring intermediate in their characters between the two parents. Such plants are called *hybrids* or *mules.* The true hybrids, which are thus produced between species of the same genus, must not be confounded with simple *cross-breeds*, which result from the crossing of two varieties of the same species; these may be termed *sub-hybrids.*

As a general rule, true hybrids can only be produced between nearly allied species, although a few exceptions occur, where hybrids have been formed between allied genera; these are called *bigeners.* The latter, however, are not so permanent as the former, for in almost all cases they are short-lived.

Hybrids rarely produce fertile seeds for many generations, and hence cannot be generally perpetuated with any certainty by them; but if they are of a woody nature, they may be readily propagated by budding, grafting, and other analogous processes. (See page 102.)

Hybrids are frequently produced artificially by gardeners applying the pollen of one species to the stigma of another, and in this way important and favourable changes are effected in the characters of our flowers, fruits, and vegetables. But varieties thus produced are not commonly true hybrids, but simple cross-breeds.

The investigations of late years would appear to show, that a similar law as regards hybridisation occurs in the Cryptogamia as in the Phanerogamia. Thus, Thuret has succeeded in fertilising the spores of *Fucus vesiculosus* with the antherozoids of *Fucus serratus*, an allied species; but he failed in his attempts to fertilise the spores of one genus of the Melanosporeous Algæ by the antherozoids of another. Other evidence has also been adduced as to the hybridisation of Cryptogamous plants, and there can be little doubt that hybrid Ferns are sometimes produced when a number of species are cultivated together, for it has been noticed that, under such circumstances, plants make their appearance which present characters of an intermediate nature between two known species.

3. Of the Fruit.—When fertilisation has been effected, important changes take place in the pistil and other organs of the flower, the result of which is the formation of the fruit, the nature and characters of which have already been fully described.

The fruit in its growth attracts the food necessary for that purpose from surrounding parts, hence, the fruiting of plants requires for its successful accomplishment an accumulation of nutrient matter, and is, therefore, necessarily an exhaustive process.

The changes produced upon the atmosphere in the ripening of the fruit depend upon the nature of the pericarp. Thus, when the pericarp preserves its green state, as also always when first formed, it has an action similar to that of the leaves; but when of other colours than green, and more especially when succulent, it evolves carbon dioxide at all times.

Chemical Constitution of Fruits.—The chemical constitution of fruits varies according to their nature and age. When the pericarp is of a dry nature, it commonly assumes a whitish or brownish colour, and its cells become thickened with hardened matters, and their cellulose walls converted into *lignin.* But when the pericarp becomes succulent whilst ripening, it assumes various tints; transpiration goes on from its outer cells, the contents of which thus become dense, and absorb the watery matters from those within them; these in like manner react upon the contents of those within them, and so there is a constant passage of fluid matters from the surrounding parts by osmotic action into the pericarp; in this way, therefore, it continues to enlarge, until it has arrived at maturity, when transpiration nearly ceases from the deposition of waxy matter in or upon the epidermal cells, and the stalk by which it is attached to the plant becomes dried up. When first formed such pericarps have a like composition with leaves, and but little or no taste. After a time they acquire an acid flavour from the formation of vegetable acids, and salts with an acid reaction. The nature of these acids and salts varies in different fruits; thus the Grape contains tartaric acid chiefly and bitartrate of potash; the Apple, malic acid; and the Lemon, citric acid. As the pericarp ripens, saccharine matter is formed, and the quantity of free acids diminishes, partly from their conversion into other matters, and partly from their combination with alkalies. In order that these changes may be properly effected, it is necessary that the fruit be exposed to the sun and air, for if grown in the dark it will continue acid; and it will be much less sweet even when developed in diffused daylight, than when freely exposed to the sun.

The origin of the sugar of fruits, and even its nature, is not satisfactorily determined. According to most observers, ripe fruits contain grape sugar; but M. Buignet states that the sugar which is primarily formed in acid fruits is *saccharose* or *cane sugar*, and that during the process of ripening, this sugar is gradually changed into *fructose* or *fruit sugar*, but very often there remains in the ripe fruit a mixture of these two sugars. The origin of the sugar is variously attributed to the transformation of the acids, cellulose, lignin, starch, dextrin, gum, and matters of a like nature. According to M. Buignet's investigations, the cause of the change of the primarily formed cane sugar into fructose is not the acids of the fruits, but appears to depend on the influence of a nitrogenous body playing the part of a glucosic ferment, analogous to that which M. Berthelot has extracted from yeast. M. Buignet adds, that 'the abundance in which starch is found distributed through the Vegetable Kingdom, leads to the supposition that it is the true source of the saccharine matter in fruits. Its presence cannot, however, be detected in green fruits, either by the microscope or by iodine, excepting in green bananas, which contain a notable quantity of starch.' The pericarp of some fruits has developed in it during the process of ripening fixed and essential oils, as well as other substances of an aromatic nature.

Ripening of Fruits.—The time when a fruit is considered ripe varies in different cases. When the pericarp is of a dry nature, the fruit is looked upon as ripe just before it dehisces; but when the pericarp is of a pulpy nature and edible, we commonly regard it as mature when most agreeable for food. Hence the Apple is considered to be ripe in a state in which the Medlar would be regarded as unripe.

When succulent fruits are ripe, they undergo another change, a species of oxidation, which produces a decay, or *bletting* of their tissues, as it has been called by Lindley. This bletting, according to Bérard, is especially evident in the fruits of the Pomeæ and Ebenaceæ, and it would appear that the more austere the fruit is, the more it is capable of bletting regularly. Bletting appears to be peculiar to such fruits, and may be regarded as a state intermediate between maturity and decay.

The time required by different plants for ripening their fruits varies much, but almost all fruits come to maturity in a few months. Some, as those of Grasses generally, take but a few days; while others, as certain of the Coniferæ, require more than twelve months.

4. Of the Seed.—Our limited space prevents us from alluding to the multitude of ways and contrivances by which the natural dissemination of seeds is effected, and to the number of seeds produced by plants. Suffice it to say, that, in all cases, a great many more seeds are matured than are required for the propagation of the species; and thus the extinction of the species in consequence of their decay, and their use for food by animals, &c., is provided against.

Vitality of Seeds.—Seeds vary very much as to the time during which they will preserve their power of germinating. This vitality is frequently lost long before they lose their value for food. Some seeds of an oily or mucilaginous nature, or which contain much tannic acid, speedily lose their vitality, and decay; this is the case, for instance, with Nuts and Acorns, and hence, when seeds of this nature are required for propagation, they must be sown immediately or within a short time of their arriving at maturity, or special means must be adopted for their preservation. Other seeds, such as those of a farinaceous nature, as Wheat and Cereal grains generally, and those with hard and bony integuments, as many of the Leguminosæ, frequently retain their vitality for years.

From numerous experiments, it would appear generally, that the seeds of the Leguminosæ and Malvaceæ preserve their vitality longest, while those of Compositæ, Cruciferæ, and Graminaceæ soon lose their germinating power. But under particular circumstances it seems certain that seeds may, and have preserved their vitality for a long period. Some remarkable instances are narrated in the author's 'Manual of Botany' (page 807), to which our readers are referred.

GERMINATION.—By germination we mean that power or act by which the latent vitality of the embryo is brought into activity, and it becomes an independent plant capable of supporting itself. The germination of Acotyledonous plants has already been sufficiently alluded to when treating of the Root, at page 125, and in the sections devoted to the Reproductive Organs and Reproduction of Acotyledonous Plants. Our further remarks will apply therefore solely to Cotyledonous plants.

Length of Time required for Germination.—The time required for germination varies much according to the nature of the seeds and the conditions under which they are placed. Generally speaking, seeds germinate most rapidly directly after being gathered. If preserved till they are quite dry, the process of germination in some cases is months in being effected, while in some seeds their capability of germination is entirely destroyed. The seed of the Garden Cress will frequently germinate in twenty-four hours, but the majority of seeds do not germinate for from six to twenty days, and some require months or even years. Germination is generally prolonged when the embryo is invested by hardened integuments or albumen, and it is usually rapid in exalbuminous seeds, more especially if such seeds have thin soft integuments. Heat is the agent which most accelerates germination.

Conditions requisite for Germination.—A certain amount of heat and moisture, and a free communication with atmospheric air, are in all cases necessary to the process of germination. Electricity is also considered by some observers to promote it, but its influence in the process is by no means proved, and if exerted it is apparently of but little importance. Light has no influence on germination in most cases, according to Hoffmann's experiments. (See also *The Effect of the Electric Light on the Growth of Plants*, page 454.)

Moisture is required to soften the parts of the seed and to take up all soluble matters; the cells of which seeds are composed are in this way enabled to expand, and the embryo to burst through the integuments, but excess of water is often injurious.

Heat is necessary to excite the dormant vitality of the embryo, but the amount required varies very much in different seeds, and probably each species has its own proper range in this respect. As a general rule from 50° to 80° Fahr. may be regarded as most favourable to germination in temperate climates, but some seeds will germinate at a temperature of 35° Fahr.; and those of many tropical plants require a temperature of from 90° to 120° Fahr., or sometimes higher, for germination.

Air, or at least oxygen gas, is required to combine with the superfluous carbon of the seed, which is thus evolved as carbon dioxide, with a sensible increase of temperature, as is well seen in the malting of Barley.

The necessity of a proper supply of oxygen is proved by the fact, that seeds will not germinate when buried too deeply in the soil, or when the soil is impervious to air. This explains how seeds may lie dormant at great depths in the soil, and only germinate when the soil is brought to the surface; and hence we see the necessity of admitting air to seeds, as in the ordinary operations of agriculture.

Process of Germination.—When the above requisites are supplied in proper proportions to suit the requirements of different seeds, germination takes place; but should any be wanting or in too great amount, the process is more or less impeded, or altogether arrested. The most favourable seasons for germination are spring and summer; and seeds sprout most readily in loose, pulverised and properly drained soil, at a moderate depth, for, under such circumstances, air, moisture, and warmth have free access. Seeds thus placed absorb moisture, soften and swell, and certain chemical changes go on at the same time in the substance of the albumen, or, when this is absent, in the cells of the cotyledonary portion, by which a proper supply of nourishment is provided for the embryo. These chemical changes chiefly consist in the conversion of starch and other analogous substances which are insoluble and therefore not in a suitable state for absorption, into soluble matters such as dextrin and grape sugar. The immediate cause of this transformation of starch is due to a nitrogenous substance called *diastase.* During these chemical actions heat is evolved, as in the *malting* of Barley, and carbon dioxide given off from the combination of the superfluous carbon in the starch and albuminoids with the oxygen of the air. The nutriment being thus made available for use, it is absorbed, dissolved in water by the embryo, which is in this manner nourished, increases in size, and ultimately bursts through the integuments of the seed. Its lower extremity or radicle (*fig.* 14, *r*), or one or more branches from it (*fig.* 165, *r*), is commonly protruded first from its proximity to the micropyle, which is the weakest point in the integuments, and by taking a direction downwards becomes fixed in the soil, whilst soon after the opposite extremity elongates upwards (*fig.* 14, *t*), and is terminated above by the plumule, which is the first terminal bud or growing apex of the stem. At the same time the cotyledonary portion is either left under ground or is carried upwards to the surface. The embryo during this development continues to be nourished from the matters contained either in the albumen or cotyledonary portion, and ultimately by continuing to absorb nutriment it is enabled to develop its first leaves (*primordial*) (*fig.* 14, *d*, *d*), and root, *r*. The young plant is now placed in a position to acquire the necessary nourishment for its further support and growth from the media by which it is surrounded, and is thereby rendered independent of the other parts of the seed; the cotyledonary portion accordingly perishes, and the act of germination is completed.

Differences between the Germination of Dicotyledonous and Monocotyledonous Seeds.—There are certain differences between the germination of Monocotyledonous and Dicotyledonous embryos, which have already been alluded to briefly (see page 124), but which require some further notice.

1. *Monocotyledonous Germination*.—The seeds of Monocotyledonous plants, in by far the majority of instances, contain albumen which, as the embryo develops, is usually entirely absorbed.

The single cotyledon of Monocotyledonous seeds, when they contain albumen, always remains entirely (*fig.* 544, *c*), or partially within the integuments, during germination. In the latter case, the intra-seminal portion of the cotyledon corresponds to the limb of the cotyledonary leaf, and the portion which elongates beyond the integuments (extra-seminal) represents the petiolar portion. The latter part varies much in length, and is commonly terminated by a sheath, which encloses the young axis with the plumule. At other times there is no evident petiolar part, but the sheathing portion enveloping the axis remains sessile on the outside of the seed, and elongates in a tangential direction to it, as in the Oat (*fig.* 165), where the cotyledon, *c*, remains within the seed, and the plumule, *g*, rises upwards from its axil into the air.

In some few Monocotyledonous Orders, such as Naiadaceæ, Alismaceæ, &c., where the seeds are exalbuminous, the cotyledon is commonly freed from the integuments, and raised upwards with the plumule.

As already noticed in the germination of Monocotyledonous embryos, e.g. the Grasses, the radicle is not itself continued downwards so as to form the root, but it gives off one or more branches of nearly equal size, which separately pierce its extremity, and become the rootlets (*fig.* 165, *r*). Each of these rootlets, at the point where it pierces the radicular extremity, is surrounded by a cellular sheath termed the *root-sheath* or *coleorhiza*, *co*. This mode of germination is commonly termed *endorhizal*; but it is by no means universal in the class (see page 124).

2. *Dicotyledonous Germination.*—The seeds of Dicotyledonous plants are either albuminous or exalbuminous, and their germination in such respects, as a general rule, presents no peculiarity worth notice. The two cotyledons either remain within the integuments of the seed in the form of fleshy lobes, as in the Horsechestnut and Oak, in which case they are said to be *hypogeal*; or, as is more commonly the case, they burst through the coats, and rise out of the ground in the form of green leaves (*fig.* 14, *c*, *c*), in which case they are *epigeal*. In the course of development the cotyledons commonly separate, and the plumule comes out from between them. In those cases where they remain within the integuments, they sometimes become more or less united, so that

the embryo resembles that of a Monocotyledon; but a Dicotyledonous embryo may be always distinguished from a Monocotyledonous one by its plumule coming out from between the bases of the cotyledons, and not passing through a sheath.

The radicle of a Dicotyledonous embryo is itself prolonged downwards by cell-multiplication just within its apex (*fig.* 163, *a*), to form the root. An embryo which germinates in this way is termed *exorhizal.*

CHAPTER IV.

SPECIAL PHENOMENA IN THE LIFE OF THE PLANT.

1. Development of Heat by Plants.—As the various parts of living plants are the seat of active chemical and other changes during their development, and in the performance of their different functions, we might conclude that their temperature would rarely or ever, under natural circumstances, correspond with that of the atmosphere around them.

We have already noticed, that during the germination of seeds a considerable development of heat takes place (page 449). This is more especially evident when a number of seeds germinate together, as in the process of malting. The development of heat in flowering has also been alluded to (page 425). The rise of temperature which thus occurs in the processes of germination and flowering is due, without doubt, essentially, to the production of carbon dioxide. We have still to inquire, whether the ordinary vital actions which are going on in plants are calculated to raise or diminish their temperature.

The experiments of several observers, and more especially of Schübeler, lead to the conclusion that the trees of our climate with thick trunks exhibit a variable internal temperature, being higher in the winter and at sunrise than the surrounding atmosphere—that is, at periods of great cold, or of moderate temperature; and lower in the summer or at mid-day—that is, at periods of great heat. In no observed cases were such trees noticed to possess exactly the temperature of the atmosphere around them. These and all other conclusions which have been at present arrived at respecting the development of heat by plants leave the question, however, in a very unsatisfactory state, and much further investigation is required upon this matter.

2. Luminosity of Plants.—Very little is positively known respecting the development of light by plants. But it seems tolerably well ascertained, on the authority of several observers, that the thallomes of some living Fungi are luminous in the dark. This luminosity or phosphorescence has been noticed in several species of *Agaricus* and the so-called *Rhizomorpha.* The mycelium of the common Truffle is also said to be luminous in the dark.

With regard to the development of light by the higher classes of plants, we have at present no very satisfactory observations to depend upon. It has been repeatedly stated, that many orange and red-coloured flowers, such as those of the Nasturtium, Sunflower, Marigolds, Orange Lilies, Red Poppies, &c., give out, on the evening of a hot day in summer, peculiar flashes of light. This peculiar luminosity of orange and red flowers is now commonly regarded as an optical illusion, and the fact of such luminosity having been only noticed in flowers with such bright and gaudy tints, appears strongly to favour such a conclusion.

The rhizomes of certain Indian Grasses have been reported to be luminous in the dark during the rainy season; and Mornay and Martius have observed, that the milky juices of some plants were luminous when exuding from wounds made in them. Martius also states, that the milky juice of *Euphorbia phosphorea* is luminous after removal from the plant, when it is heated.

3. Electricity of Plants.—Disturbances of electrical equilibrium are undoubtedly connected with the various chemical and mechanical changes which take place in plants. By the medium of a galvanometer, Ranke, Velten, Burdon Sanderson, and others, have demonstrated that there exists in plants an electric current from the transverse to the longitudinal section of a vegetable fibre, similar, but in the contrary direction, to that shown by Du Bois Reymond to exist in the muscles, &c., of animals. It is also found that the internal tissue of land plants is always electro-negative to the cuticularised surface.

The Effect of the Electric Light on the Growth of Plants and Production of Chlorophyll.—Recent experiments made by Dr. Siemens seem to prove that the electric light aids the growth of plants, produces chlorophyll, increases the brilliancy of flowers, and promotes the ripening of fruits. By sowing seeds of rapidly growing plants and exposing them to the same conditions with the exception of light, he found that those grown in the dark were etiolated and soon withered; those exposed to daylight with a fair share of sunlight were vigorous, and of a good green colour; but those exposed to the electric light for six hours per day only, being in darkness the other eighteen hours, were vigorous though less green; while those exposed to daylight and electric light successively, were the most vigorous, and the green of their leaves of a darker hue. This shows that plants may for a time grow continuously without rest, i.e. without sleep; but for what length of time this endurance would continue further experiments are required to prove. The electric light seems therefore to affect plants in a similar manner to the continuous summer sun in northern latitudes, where Dr. Schübeler found that the arctic sun caused plants to produce more brilliant flowers and richer and larger fruit than if the same plants had been grown with an alternation of light and darkness.

4. Movements of Plants.—Three kinds of movements have been described in plants:—1. Motions of entire plants, such as those which occur in the Oscillatorieæ, Diatomeæ, and some other forms of the lower Algæ; and of parts, e.g. the antherozoids, connected with the reproductive processes in some of the lower kinds of plants. 2. Movements produced in parts of plants which are dead, or which, at least, have lost their active vitality. Such movements may be noticed in almost all the great divisions of plants, and are more or less connected with some reproductive function. We include here the bursting of anthers in the higher classes of plants, and that of spore-cases in the lower; the dehiscence of fruits, the separation of the component carpels from each other in the Euphorbiaceæ and Geraniaceæ, and many other phenomena of a like nature. 3. Movements which occur in the living parts of plants when in an active state of growth, &c.

The first two classes of movements have been already alluded to in various parts of this work. The movements of the first class appear to depend upon a rotation of the protoplasmic cell-contents, the cause of which is at present unexplained; or to the presence of cilia upon their surfaces. Movements of the second kind are entirely mechanical, and produced by the varying conditions of the different tissues as to elasticity and power of imbibing moisture.

The third class of movements must be more particularly noticed. They only occur during active vegetation. The directions taken by organs properly come under this head. With regard to the stem the extensive researches of Darwin on Twining Plants and Tendrils are full of interest. The ends of such organs have the power of spontaneously revolving; and this they constantly do, usually from right to left, once in about two hours; to this action Sachs has applied the term of *revolving nutation*, which Darwin proposes to simplify into that of *circumnutation*. So soon as the organ meets with a support its motion is arrested, and it becomes spirally twined round by the arrest of the movement of successive portions. Tendrils contract spirally soon after they have laid hold of a support, and so draw up the stem to which they are attached. The movements belonging to this third class have been divided by Schleiden in the following manner:—

1. Movements which evidently depend on external influences. These are divided into two—
    a. Periodical. *b.* Not periodical.
2. Movements independent, at least to some extent, of external influences, which are also divided into—
    a. Periodical. *b.* Not periodical.

(1.) MOVEMENTS DEPENDING ON EXTERNAL INFLUENCES.—*a. Periodical.*—Under this head we include such movements as those of certain leaves and the petals of flowers, which occur at particular hours, the organs remaining in the new position thus taken up until the return of a particular period, when they resume as nearly as possible their original position. In leaves, these periodical movements consist in the closing up of such organs towards the evening and their expansion in the morning. In the petals of flowers great differences occur in opening or closing at particular hours of the day; and, by observing these changes in a variety of flowers, Linnæus and others have drawn up what has been termed a floral clock. This periodical closing up of leaves and flowers has been called the sleep of plants. The compound leaves of certain Leguminosæ and Oxalidaceæ are marked illustrations of these periodical movements, which are probably all indirectly dependent upon the varying conditions of light to which the parts of the plant in which they occur are exposed. All these movements Darwin considers to be due to modified circumnutation. This author says ('Movements of Plants,' p. 395) : 'In *Lupinus* the leaflets move either upwards or downwards; and in some species (for instance, *L. luteus*), those on one side of the star-shaped leaf move up, and those on the opposite side move down; the intermediate ones rotating on their axes; and by these varied movements the whole leaf forms at night a vertical star, instead of a horizontal one as during the day. Some leaves and leaflets, besides moving either upwards or downwards, become more or less folded at night, as in *Bauhinia* and in some species of *Oxalis*. The positions, indeed, which leaves occupy when asleep are almost infinitely diversified: they may either point vertically upwards (*fig.* 657, B) or downwards (*fig.*

FIG. 657.

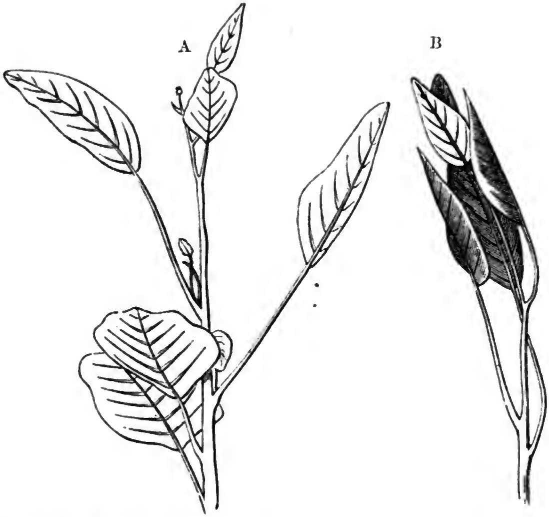


Fig. 657. *Nicotiana glauca*. A. Shoot with leaves expanded during the day. B. The same with the leaves asleep at night, pointing vertically upwards. After Darwin.

658, B); or, in the case of leaflets, towards the apex or towards the base of the leaf, or in any intermediate position. . . .

'The nyctitropic movements of leaves, leaflets and petioles are effected in two different ways—firstly, by alternately increased growth on their opposite sides, preceded by an increased turgescence of their cells; and secondly, by means of a pulvinus or aggregate of small cells, generally destitute of chlorophyll, which become alternately more turgescent on nearly opposite sides, and this turgescence is not followed by growth except during the early age of the plant.'

FIG. 658.

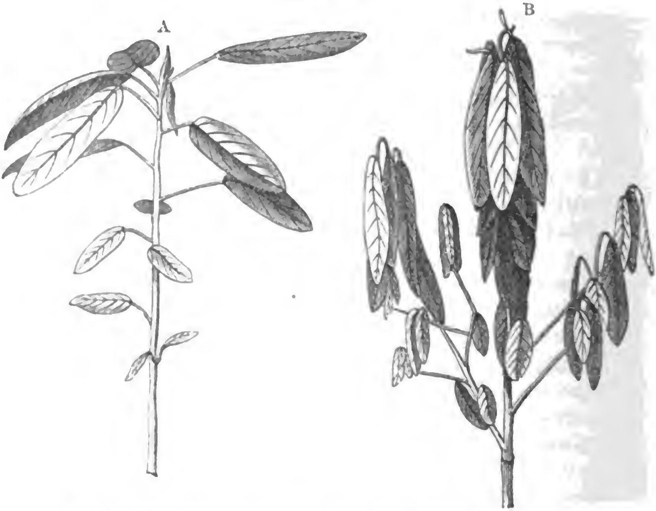


Fig. 658. *Desmodium gyrans.* A. Stem with leaves during the day. B A similar stem with leaves asleep at night, pointing downwards. After Darwin.

b. *Not periodical.*—Such movements are exhibited in a number of plants both in the leaves and in their reproductive organs. In the leaves they are well seen in certain species of *Oxalis*, *Mimosa* (*fig.* 263), and in *Dionæa muscipula* (*fig.* 265). In the reproductive organs they may be noticed in the curving inwards or outwards of the stamens of certain plants, such as those of *Berberis vulgaris* and other species, *Helianthemum vulgare* and other Cistaceæ; also in the stigmas of the Lobeliaceæ, &c. All the above movements are produced by external agency, such as the action of insects, the agitation caused by the wind, &c. Other movements which fairly come under this heading, and which, like the nyctitropic movements, are by Darwin regarded as being due to modified circumnutation, are *positive* and *negative heliotropism*, *positive* and *negative geotropism*, &c.

Positive heliotropism is the growing towards the source of light. It has been long known that plants grown in comparative darkness increase in length more rapidly than those exposed to a stronger light—i.e. that light appears to have a retarding influence on growth—therefore, where a plant or part of a plant exhibits positive heliotropism, it is found that the part away from the light has attained a greater length than that towards it.

Some few vegetable organs, as the stem of Ivy, and many roots, exhibit *negative heliotropism*, where, as they grow away from the light, the parts next the source of illumination grow most.

Positive geotropism or *gravitation* is the term applied to the force which influences the direction of growth of most roots, especially of primary roots, which usually point directly downwards to the centre of the earth.

Negative geotropism, on the other hand, signifies the direction taken by most stems, trees, &c., being exactly opposite to that sought by the roots—i.e. upwards, or away from the centre of the earth.

As the terms *positive* and *negative heliotropism* and of *positive* and *negative geotropism* are frequently used carelessly, the qualifying expressions *positive* and *nega-*

tive being frequently omitted, Darwin adopts the term *heliotropism* in the sense of bending *towards* the light; *apheliotropism* for the contrary direction, i.e. away from the source of illumination; and, in the same manner, *geotropism* to imply towards the earth, and *apogeotropism* for bending in opposition to gravity, or from the centre of the earth.

In addition to the foregoing terms, *diaheliotropism* is sometimes used to express a position more or less transverse to the light which induced it; and *diageotropism* to a similar position with regard to the radius of the earth.

FIG. 659.

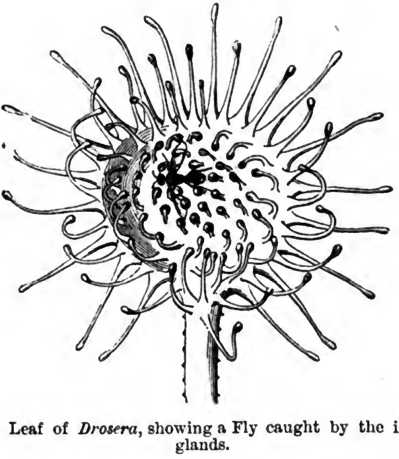


Fig. 659. Leaf of *Drosera*, showing a Fly caught by the incurved glands.

Irritability.—It has been already stated that some movements of plants are dependent upon the agency of insects. But though it has long been known that insects thus induce movements in certain plants, such as *Drosera*, *Dionæa*, *Nepenthes*, &c., it is only of late years, by the observations of Darwin, Hooker, Vines, Riess, Wills, and others, that we have learnt that the insects, which by these movements are caught, serve for nutrition, being dissolved and absorbed. It has been also demonstrated that this solution of nitrogenous matters is due to the presence of a kind of ferment which closely resembles that of the peptic glands of animals. It has likewise been proved that this ferment is only efficient when associated with an acid; and hence this solution is a true digestive process like that of animals. During the solution and absorption of these nitrogenous matters the protoplasm retracts from the walls of the cells in the form of a ball. In *fig.* 659 is shown a leaf of *Drosera* (Sundew) where some of the glands or glandular hairs have bent over and caught an insect. Such plants are now commonly termed *carnivorous*.

To plants which are thus stimulated to movement by chemical or mechanical means the term *irritable* is applied; thus it is by reason of their irritability that the leaves and branches of the Sensitive plants (*fig.* 263) droop on contact with any foreign body.

FIG. 660.

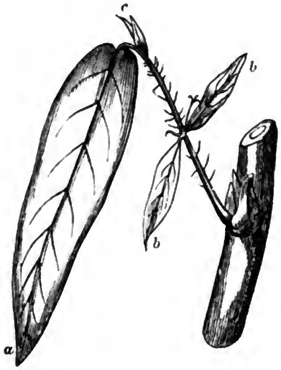


Fig. 660. A portion of a branch, with a leaf of *Desmodium gyrans*. The leaf, which is compound, consists of a large terminal leaflet, *a*, and two smaller lateral ones, *b*, *b*. There are also two other rudimentary leaflets, marked *c*, near the terminal leaflet.

(2.) MOVEMENTS INDEPENDENT, AT LEAST TO SOME EXTENT, OF EXTERNAL INFLUENCES.—a. *Periodical.*—These movements are seen in some of the leaflets of certain tropical species of *Desmodium*, and more especially in those of *Desmodium gyrans* (*fig.* 660). The leaf in this plant is compound, and bears three leaflets;

the terminal one, *a*, being much larger than the two lateral ones, *b*, *b*. There are also two other rudimentary leaflets, marked *c*, near the large terminal one. This large terminal leaflet, when exposed to the influence of a bright light, becomes more or less horizontal (*fig.* 658, A), but it falls downwards on the approach of evening (*figs.* 660, *a*, and 658, B). This movement is clearly analogous to the sleep of plants, and, therefore, comes under the head of movements depending on external influences, as previously described (page 457). But the lateral leaflets, *b*, *b* (*fig.* 660), exhibit a constant movement during the heat of the day, advancing by their margins towards the large terminal leaflet, and then retreating towards the base of the common petiole. This movement takes place first on one side and then on the other, so that the point of each leaflet describes a circle. The movements resemble those of the arms of the old semaphore telegraphs, and hence this plant has been termed the Telegraph plant. They go on, although to a less extent, even in the dark, and are most evident when the plants are in a vigorous state of growth, and when exposed to a high temperature. No satisfactory explanation has yet been given of the direct cause of this movement. Somewhat similar movements have been observed in the radicles of many plants.

b. *Not periodical.*—These movements occur in the reproductive organs of a large number of the Phanerogamia. The stamens sometimes curve inwards separately towards the stigma, as in *Ruta graveolens* (*fig.* 427); or in pairs, as in *Saxifraga tridactylites*. They afterwards commonly return as nearly as possible to their former position. In *Parnassia* the arrangement appears to be one adapted, as the anthers are extrorse, to prevent self-fertilisation (see page 442). In *Passiflora*, *Nigella sativa*, certain Onagraceæ and Cactaceæ, &c., the styles move to the stamens; while in other Onagraceæ and certain Malvaceæ, &c., both styles and stamens move towards each other. No explanation of a satisfactory nature has been given of the cause of these movements, but their object is doubtless to assist in the process of fertilisation.

5. ODOURS OF PLANTS.—These are very various in kind, many being highly agreeable, others excessively offensive, while others again, though pleasant in small quantity, become disagreeable in larger amount. The source of the particular odour is often a volatile oil or other product contained in the glands or receptacles of secretion of the plants; but in some cases no such origin is found, and the source of the odour is unknown, whilst its nature defies analysis. It is generally considered that smell is due to the giving off of minute particles into the air; Morren, however, from observations on the flowers of Orchids, was led to the inference that in some cases it depended on a physiological cause. He observed that the aromatic odour of *Maxillaria*, which continued to be exhaled so long as the flowers were unfertilised, was lost a little while after pollen was applied to the stigma.

Though chiefly developed under the influence of solar light, there are not a few plant-odours which are given off in the evening, or at night. Several Orchids, *Cestrum nocturnum*, *Hesperis tristis*, *Lychnis vespertina*, and *Cereus grandiflorus*, are examples. In the last-named plant, the odour is given out in intermittent puffs.

There seems to be a connexion between the colour of the flowers and their odour; thus it has been observed that white flowers are very frequently fragrant, whilst brown and orange ones have often a fœtid smell,—the so-called Carrion-flowers (*Stapeliæ*), certain Aroids, some Balanophoraceæ, and the *Rafflesiæ*, being examples. The flowers of Monocotyledons are more often odorous than those of Dicotyledons.

INDEX.

*** The technical terms mentioned below are explained at the pages referred to, and thus the Index may be also used as a Glossary.

Abaxile embryo, 325
Abortive, 227
Abruptly pinnate, 163
Absorption, 379, 380, 382, 399, 410, 415
— by the root, 391
Acaulescent, 69
Accessory buds, 107
Accrescent, 216
Accumbent, 324
Acerose, 157
Achænium, 291
Achene, 291
Achlamydeous, 20
Acicular, 161
Acicular raphides, 35
Acotyledonous, 14, 333
— leaves, 175
— roots, 125
— stem, 75, 95
— venation, 147
Acotyledones, 14, 333
Acrogenous, 72
— stem, 72, 95
Acropetal, 188
Acropetally, 104, 188
Acuminate, 157
Acute-pointed, 156
Adelphous, 241
Adherent calyx, 212
— ovary, 262
— stipules, 169
Adnate anther, 234
Adnate filament, 240
— stipules, 169
Adventitious buds, 106
— root, 117, 119, 125
Æcidia, 354
Æcidium fruits, 354
Aerial bulbs, 115
— leaves, structure of, 131
— roots, 120
Æstivation, 204
Age of dicotyledonous trees, 80
— — monocotyledonous trees, 95
Air cavities, 67, 390
— cells, 390
— plants, 122
Alæ, 220
Albumen, 23, 317
Albuminous, 317
Alburnum, 80, 394, 417
Aleurone grains, 35, 36
Algæ, 368
Alternate leaves, 138
Alternation of generations, 337, 338, 433
Amentaceous, 189
Amentiferous, 189
Amentum, 189
Amphitropous, 309, 326
Amplexicaul, 137, 168
Anatropous, 309
Andrœcium, 18, 20, 227, 238
Androphore, 242
Androus, 238

ANG

Angiospermia, 12
Angiospermous, 303, 433
Anisostemonous, 238
Annual herbs, 109
— layers of wood, 78
Annular cells, 45
— vessels, 50, 51, 95
Annulate, 335
Annulated root, 127
Annulus, 335, 346, 356
Anomalous leaves, 171
Anthela, 192
Anther, 20, 227, 230
Antheridia, 9, 336, 339
Antherozoid, 9, 343, 347, 367
Anthesis, 208
Anthocarpous, 300
Anthodium, 193
Anthotaxis, 176
Antipodal cells, 306, 439
Antitropous, 326
Apex of leaves, 130, 155
Apheliotropism, 460
Apical cell, 394, 396
— dehiscence, 237
— style, 266
Apicilar, 266, 274
Apicular, 286
Aploperistomous, 346
Apocarpous, 256, 274
— fruits, 290
Apogeotropism, 460
Apothecia, 362
Appendages of the epidermis, 59
— — — calyx, 214
— — — corolla, 223
Appendiculate, 228, 235
Archegonia, 9, 336, 342, 343, 346
Aril, 314
Arillode, 315
Arillus, 314
Arrangement of leaves, 136, 137
Arrow-shaped leaves, 159
Articulated, 130
Articulation, 166
Ascending axis, 14
— inflorescence, 188
— metamorphosis, 330
— ovule, 304
— radicle, 326
— sap, 417
Ascent of the sap, 417
Asci, 360, 363
Ascidia, 173
Ascomycetes, 357
Ascospores, 360, 363
Asexual, 332, 337

BOR

Assimilation, 29, 402, 403, 421
Attachment of filament, 234
Attraction, adhesive, 384
— capillary, 384
Auriculate, 159
Awl-shaped, 157
Axial embryo, 325
Axil, 130
Axile embryo, 325
— placenta, 263
Axillary, 130, 186, 187
— inflorescence, 186, 187
— stipules, 170

BACCA, 298
Baccate, 299
Barbed hairs, 61
Bark, 70, 75, 84
— functions of, 396
— growth of, 86
Base of leaf, 129
Basidia, 356
Basidiomycetes, 354
Basifixed, 234
Basilar, 286
— style, 266
Bast, 49
— fibre, 49
— tissue, 49
— vessels, 53
Bell-shaped, 221
Berried, 299
Berry, 298
Bicrenate, 150
Biennial herbs, 109
Bifid, 151, 267, 269
Bifoliate, 164
Bigeners, 443
Bijugate, 163
Bilabiate, 212, 222
Bilobate, 269
Bilocular, 230
Binate, 164
Biparous cyme, 198
Bipartite, 151, 267
Bipinnate, 163
Bipinnatifid, 152
Bipinnatipartite, 152
Bipinnatisected, 152
Bisected, 151
Biserrate, 149
Bisexual, 226
Biternate, 165
Blade, 16, 130, 142
Bletting, 446
Blunt, 155
Bordered, 313

Bordered pits, 42
Bostrycoid, 105
Bostryx, 201
Botany, departments of, 1
— object of, 1
— structural, 2
Botryoid, 186
Botryose, 186
Bracteated, 178
Bracteoles, 177
Bractlets, 177
Bracts, 18, 137, 176, 327
Branches, 103
Branching, 103
— corymb, 192
— spadix, 189
Bristles, 63
British gum, 34
Brotherhood, 241
Budding, 102
Buds, 98
— and ramification, 99
— naked, 100
— scaly, 99
Bulb, 113
Bulbils, 115
Bulblets, 115
Bundle-sheath, 97
Bush, 109

CADUCOUS, 185, 215, 225
Caladium, 399
Calyptra, 344, 349
Calyptrate, 215
Calyx, 18, 208
Cambium, 72, 82
— cells, 82
— layer, 75, 82
Campanulate, 212, 221
Campylotropous, 309
Canal cell, 435
Capillary, 228
Capitate, 61, 271
Capitulum, 193
Capsular, 295
Capsule, 294, 334, 335, 337, 344, 348
Carcerule, 294
Carina, 220
Carnivorous plants, 461
Carpel, 21, 250, 329
Carpellary, 22
Carpophore, 272, 297
Caruncules, 315
Caryophyllaceous, 219
Caryopsis, 293
Cataphyllary leaves, 129
Catkin, 189
Caudex, 108
Caudicle, 245
Caulescent, 69
Caulinary stipules, 169
Cauline leaves, 136
Caulis, 108
Caulome, 15, 68, 394
Cell-contents, 24
Cell-division, 377, 378, 379
Cell-formation, 377
Cell-membrane, 41
Cell-multiplication, 377
Cell-nucleus, 27
Cells, 16, 23, 230, 259
— with bordered pits, 42, 49
Cell-sap, 25, 27
Cellular envelope, 85
— plants, 9
— system, 55, 69
Cellulose, 4, 24, 33
Cell-wall, 4, 24, 41, 377
— structure of, 41
Central placenta, 263
— — free, 263
Centrifugal, 326
Centripetal, 188, 326
Ceratium, 296
Chalaza, 308
Characeæ, 365, 386
Charas, 365, 386, 428
Chemical constitution of fruits, 444
Chlorofucin, 406
Chlorophyll, 28, 454
Chlorophyll bodies, 29
— corpuscles, 29
— grains, 29
— granules, 28
Cicatrix, 166
Cicinal dichotomy, 105
Cicinnus, 201
Circinate, 141
— cotyledons, 323
Circular æstivation, 205
Circulation, 417
Circumnutation, 456
Circumscissile, 279, 285
Cirrhus, 103
Cladode, 184
Clathrate cells, 53
Clavate, 161, 228
Claviceps, 357
Claw, 217
Clawed, 217
Cleft, 211, 220, 267, 269
Climbing, 107
Closed vascular bundles, 74, 89

CLO

Cloves 114
Club-mosses, 341, 430
Club-shaped, 228
Coat of pollen-cell, 246
— — seed. 312
Coated bulb, 114
Cocci, 282
Cochlear, 206, 207
Cœnanthium, 183
Cohesion of stamens, 240
Coleorhiza, 120, 124, 451
Collateral, 304
Collecting hairs, 267
Collective fruits, 300
Collenchyma, 47
Colour of filament, 229
— — flowers, 425
— — leaves, 405
— — testa, 312
Columella, 278, 345, 350
Coma, 313
Commissure, 297
Common calyx, 193
— petiole, 148, 166
Comose, 313
Comparative anatomy of plants, 2
Complete flower, 18
Composition of fruit, 275
— — leaves, 148
— — pericarp, 275
— — starch, 33
Compound corymb, 192
— flower, 193
— fruit, 274
— gynœcium, 256
— hairs, 60
— leaves, 131, 148, 161
— ovary, 258, 260
— petiole, 166
— pistil, 250
— roots, 125
— spadix, 189
— style, 267
— umbel, 195
Conceptacles, 373
Conditions of germination, 448
Conducting tissue, 254
Conduplicate, 140, 323
Cone, 190, 300
Confluent fruits, 300
Conglomerate raphides, 35
Conical hairs, 61
— leaf, 161
— root, 128
Conidia, 351
Conjugation, 369
Connate, 137, 240
Connective, 230, 234

CYN

Connivent, 209, 217
Constructive materials, 422
Contents of cells, 24, 247
Contorted æstivation, 206
Contracted cyme, 201
Convolute, 141, 206
Cordate, 159
Cordate-lanceolate, 159
Cordate-ovate, 159
Cork, 86
— cambium, 87
Corky layer of bark, 85, 86
Corm, 116
Cormophytes, 11, 70
Corolla, 18, 216
Corona, 225
Corpuscula, 435
Corrugated, 204
Cortex, 84
Corymb, 192
Costate, 146
Cotyledones, 14
Cotyledons, 13, 136, 319
Creation, inorganic, 1
— organic, 1
Creeping stem, 111
— root, 112
Cremocarp, 297
Crenate, 150
Crenulated, 150
Crisped, 150
Cross-breeds, 443
Cross-fertilisation, 442
Crossing, 442
Crown of the root, 136
Crowned corolla, 225
Cruciate, 219
Cruciform, 219
Crude sap, 417
Crumpled, 204
Cryptogamous, 11, 332
Crystalloids, 35, 36
Culm, 108
Cuneate, 158
Cupule, 180, 298
Curled, 150
Curved ovules, 309
— veined, 147
Cuspidate, 157
Cuticle, 56
Cuticularised, 56
Cylindrical cell, 38
— leaf, 161
— style, 267
Cyme, 197
— false, 105
Cymose, 105, 186
Cynarrhodum, 292

Cypsela, 298
Cystoliths, 35
Cystopus, 351
Cytoblast, 378
Cytogenesis, 377

DEATH of the leaf, 408
Deciduous, 130, 178, 185, 215, 226, 230, 266
Declinate, 229
Decomposed, 153
Decompound, 163, 165
Decurrent, 137
Decussate, 138
Decussation, 138
Definite inflorescence, 186, 187, 195, 196, 197, 203
— ovules, 303
Definition of a plant, 2
Definite vascular bundles, 74, 89
Defoliation, 407, 408
Degradation products, 422
Dehiscence of anther, 236
— — fruit, 277, 279
Dehiscent fruit, 277
Dentate, 149
Departments of botany, 1
Dermatogen, 117
Descending axis, 14, 116, 390
— radicle, 326
— sap, 417
Descent of the sap, 422
Determinate inflorescence, 186, 187, 195, 196, 197
Development of the anther, 232
— — floral envelopes, 425
— — heat, 452
— — leaves, 409
— — ovule, 305
— — roots, 393
— — starch, 31
— — stem, 396
— — stomata, 389
Dextrin, 34
Diachænium, 297
Diadelphous, 241
Diageotropism, 460
Diaheliotropism, 460
Dialypetalous, 218
Dialysepalous, 210
Diandrous, 238
Diastase, 449
Dichasium, 105, 198
Dichlamydeous, 19
Dichotomous branching, 103, 104
— cyme, 198
Dichotomy, 104
— bostrycoid, 105
— cicinal, 105
— helicoid, 105
— scorpioid, 105
— sympodial, 104
— true or normal, 104
Diclinous, 226
Dicoccous, 282
Dicotyledones, 14, 319
Dicotyledonous, 319
— embryo, 321
— germination, 451
— leaves, 175
— roots, 124
— stem, 75
Didynamous, 243
Diffusion of fluids, 384
— — gases, 383
Digitate, 154, 165
Digitipartite, 154
Digynous, 256
Dimerous, 261
Dimorphic, 243, 442
Diœcious, 226, 342, 346
Diploperistomous, 346
Diplotegia, 295
Direct metamorphosis, 330
Direction of filaments, 229
Disc-bearing woody tissue, 49
Disk, 248
Dissected, 151, 154
Dissepiment, 259
Distractile, 235
Divergent, 209, 217
Dorsal suture, 251, 276
Dorsifixed, 234
Dotted cells, 42
— leaves, 66
— vessels, 50
Doum palm, 93
Drupaceous, 290
Drupe, 290
Drupe-like, 290
Duplicato-dentate, 150
Duramen, 80
Duration of calyx, 215
— — corolla, 225
— — filament, 230
— — the leaf, 130

EARTHY constituents, 414
Ebracteated, 178
Eccentric embryo, 325
Ectoplasm, 26, 27
Effects of electric light, 454

EFF

Effects of gases upon leaves, 404
Egg-shaped, 158
Elaborated sap, 417
Elaboration of cell-contents, 386
Elaters, 338, 349, 350, 429
Electricity of plants, 454
Elementary structure, 6, 23, 376
Elliptical, 157
Elliptico-lanceolate, 159
Elongated parenchyma, 46
Emarginate, 155
Embracing, 137
Embryo, 12, 23, 318, 324
— buds, 106
— cell, 432
— nodules, 106
— sac, 305, 336, 432
Embryonal cell, 9, 343, 348
Embryonic vesicles, 305
Emergences, 63
Empty bracts, 178
Enantioblastic, 325
Endocarp, 275
Endogenous, 71
— stem, 88, 90
— — age of, 95
— — anomalous structure of, 94
— — growth of, 89
Endoplasm, 26
Endopleura, 312, 314
Endorhizal, 124, 451
Endosmose, 384
Endosperm, 23, 317
— cells, 316
Endospore, 352
Endostome, 307
Endothecium, 233
Ensiform, 161
Entire calyx, 211
— corolla, 220
— leaf, 149
— style, 267
Enveloping, 206
Epiblema, 118
Epicalyx, 215
Epicarp, 275
Epidermal appendages, 59
— layer, 374
— tissue, 55, 388
Epidermis, 56, 75
— functions of, 388
Epigeal, 451
Epigone, 343, 347
Epigynous, 240, 250
Epipetalous, 238
Epiphragma, 346
Epiphytes, 121
Episperm, 312

FIB

Equal leaf, 157
Equally pinnate, 163
Equisetaceæ, 337, 432
Equitant, 142, 323
Erect embryo, 326
— ovule, 304
Ergot, 358
Essential organs, 21
Etærio, 292
Etiolated, 403
Evergreen, 130
Exalbuminous, 317
Exannulate, 335
Excipulum, 362
Excrescent, 185
Excretion by roots, 392
Excretions, 403
Exhalation by leaves, 397
— of gases, 399
Exogenous, 71
— stems, 75, 79
Exorhizal, 124, 452
Exosmose, 384
Exospore, 352
Exostome, 307
Exothecium, 233
Exserted, 242
Exstipulate, 17, 131, 169
Extine, 246, 434
Extra-axillary, 130, 184
Extrorse, 232

Fall of the leaf, 407
False arillus, 315
— bark, 71, 88, 90
— cyme, 105
— dissepiment, 259
Farinaceous albumen, 318
Fasciated branches, 107
Fascicle, 139, 201
Fascicled leaves, 139
Fasciculated root, 127
Faux, 211, 220
Feather-veined, 145
Feathery, 213, 214
Female apparatus, 433
— flower, 22
Ferns, 333, 432
Fern proper, 337
— stems, 95
— internal structure of, 96
— growth by buds, 97
Fertile, 227
Fertilisation, 22
Fibres, 39, 44, 49
Fibrilliform cells, 39
— tissue, 47

Fibrils, 63, 118
Fibrous cells, 44
— root, 126
Fibro-vascular bundles, 39, 49, 72, 89
— system, 55, 69, 85
— — of leaves, 132
— tissue, 55
Fid, 151
Fiddle-shaped, 153
Filament, 20, 227
Filices, 333, 432
Filiform, 228, 267
Fimbriated, 217
Fissiparous, 378
Fissured calyx, 211
— stigma, 269
Fissures of leaves, 151
Fixed embryo, 102
Fleshy albumen, 318
— cotyledons, 322
Floral envelopes, 208, 424, 425
Florets, 193
Flower, 18, 216
— complete, 18
Flowering plants, 11
Flowerless plants, 11, 332
Flower-stalk, 17, 182
Folded leaves, 140
Foliaceous, 134, 213, 322
Foliage leaves, 129
Folioles, 148
Follicle, 290
Food of plants, 410
— sources of, 410
Foramen, 307
Forked anther, 235
— filament, 228
— venation, 148
Formation of cells, 377
— — organic compounds, 402
— — pollen, 243
— — wood, 395
Forms of anther lobes, 235
— — cells, 37, 248
— — filament, 227
— — hairs, 60
— — leaves, 161, 171
— — peduncle, 184
— — petiole, 167
— — roots, 126
— — seeds, 311
— — stems, 107
— — style, 267
Fossil botany, 2
Fovilla, 247, 434
Free calyx, 213
— cell-formation, 377, 378, 382
Free central placenta, 263, 264
— ovary, 262
— stamens, 240
Fringed, 217
Fronds, 11, 95
Fructification, 354
Fructose sugar, 445
Fruit, 22, 273, 330, 444
— apocarpous, 274
— compound, 274
— dehiscent, 277
— indehiscent, 277
— nature of, 273
— ripening of, 446
— simple, 274
— spurious, 274
— sugar, 445
— syncarpous, 274
Fucus, 373, 443
Fugacious, 215
Functions, 376
— of bark, 396
— — bracts, 424
— — epidermal appendages, 389
— — — tissue, 388
— — essential organs, 426
— — floral envelopes, 424
— — glands, 390
— — hairs, 389
— — intercellular system, 390
— — laticiferous vessels, 387
— — leaves, 397
— — medullary rays, 395
— — organs of reproduction, 424
— — parenchyma, 376
— — prosenchymatous cells, 387
— — stem, 394
— — stomata, 388
— — vessels, 387
Fundamental tissue, 76, 83, 86
Fungi, 350
Funiculus, 302, 310
Funnel-shaped, 221
Fusiform cell, 39
— root, 129

GALBULUS, 300
Gamopetalous, 220
Gamosepalous, 210
Gaping, 222
General characters of fruit, 273
— involucre, 179
— morphology, 6, 326
— physiology, 409
General umbel, 195
Geographical botany, 2
Geotropism, 460

GER

Germ-cell, 9, 336, 343, 348, 432
Germinal corpuscles, 336
— vesicles, 305, 438
Germination, 14, 447
— conditions of, 448
— dicotyledonous, 451
— monocotyledonous, 450
— process of, 449
— time required for, 447
Gibbous, 214, 224
Glands, 63, 390
— compound, 64
— external, 63
— internal, 63, 65
— nectariferous, 66
— sessile, 64
— simple, 64
— stalked, 63
Glandular hairs, 64
Glans, 298
Globoids, 35, 37
Globose, 212
Globule, 365, 427
Glochidiate, 61
Glœocapsa, 29
Glomerule, 201
Glumellules, 182
Glumes, 182, 190
Gonidia, 361
Grafting, 102
Granulose, 33
Gravitation, 459
Green layer of bark, 85
Growing part, 394
— point, 393
Growth of the bark, 86
— — endogenous stems, 89
Guard-cells, 58
Gymnospermia, 12
Gymnospermous, 303, 433
Gymnostomous, 346
Gynandrous, 240
Gynia, 256
Gynobase, 267
Gynobasic, 267
Gynœcium, 18, 20, 250, 255
Gynophore, 261, 278
Gynostemium, 240
Gyration, 385

Hairs, 60, 389
Halbert-shaped, 159
Half-adherent calyx, 262
Half-equitant, 142
Half-inferior calyx, 262
Half-superior calyx, 262
Hastate, 159

INC

Hastate-auricled, 159
Haustoria, 123, 351
Head of flowers, 193
Heart-shaped, 159
Heart-wood, 80
Heat of plants, 452
Helicoid cyme, 199, 201
— dichotomy, 105
Heliotropism, 459, 460
Hemicarp, 297
Hepaticaceæ, 346, 428
Herbs, 108
Hermaphrodite, 226, 342
Hesperidium, 296
Heterœcism, 353
Heterocysts, 369
Heterophyllous, 159
Heterorhizal, 125
Heterostyled, 442
Heterotropous, 309
Hidden-veined, 143
Hilum, 32, 302, 308, 310
Histology, 2, 23
Homoblastic, 325
Homologous formations, 176
Homotropous, 326
Hooded, 210
Hood-shaped, 161
Hooked hairs, 61
Horizontal ovule, 304
— system, 55, 70
Horny albumen, 318
Horsetails, 337, 432
Host, 122
Hybridation, 422
Hybridisation, 442
Hybrids, 443
— production of, 442
Hymenium, 355
Hypanthodium, 183
Hyphæ, 7, 47
Hyphal tissue, 47
Hypochlorin, 403
Hypocotyledonary axis, 319
Hypocrateriform, 221
Hypoderma, 47
Hypodermiæ, 352
Hypogeal, 451
Hypogynous, 238, 249
Hypothecium, 362
Hypsophyllary leaves, 137, 176

Illegitimate fertilisation, 442
Imbricate, 142
Imbricated æstivation, 206
Imparipinnate, 163
Incision of leaves, 150

Included, 242
Incumbent, 324
Incurved, 229
Indefinite inflorescence, 186, 187, 188, 193, 203
Indefinite vascular bundles, 72
Indehiscent fruit, 20, 277
Independent movements, 461
Indeterminate inflorescence, 186, 187
Individual peculiarities, 102
Induplicate, 142, 205
Indusium, 268, 334, 356
Inferior calyx, 213, 262
— fruit, 275
— ovary, 220, 262
— radicle, 326
— syncarpous fruit, 297
Inflexed, 140
Inflorescence, 18, 176, 186
— axillary, 186, 187
— definite, 186, 195, 203
— determinate, 186, 195
— indefinite, 186, 187, 188, 203
— indeterminate, 186, 187
— mixed, 203
— terminal, 195
Infra-axillary, 130
Infrutescences, 300
Infundibuliform, 221
Innate, 234
Inner bark, 85
— coat, 314
Inorganic constituents, 413
Insertion of leaves, 136
— — stamens, 238
Integuments of seed, 23, 312
Integumentum simplex, 306
Intercellular canals, 66, 390
— passages, 66
— spaces, 66, 390
— substance, 68
— system, 66, 390
Interlacing tissue, 47
Internal embryo, 325
— structure of leaves, 131
— system, 85
Internodes, 129
Interpetiolar, 170
Interruptedly pinnate, 163
Intine, 246, 434
Intracellular circulation, 385
Introrse, 232
Inverse ovule, 304
Inversely egg-shaped, 158
— heart-shaped, 159
Inverted embryo, 326
— ovule, 309
Involucel, 179
Involucre, 179, 334
Involute, 141
Irregular, 38, 210, 211
— corolla, 219, 222
Irritability, 460
Isostemonous, 238

JOINT, 166
Jugate, 163
Jungermannia, 9, 349

KEEL, 220
Kernel, 23, 312, 316
Kidney-shaped, 159
Kinds of branches, 109
— — cells, 45
— — fruit, 287
— — inflorescence, 186, 188, 193, 197
— — placentation, 263
— — stems, 109
Kingdom, animal, 1
— mineral, 1
— vegetable, 1
Knots, 101

LABIATE, 212, 222
Laciniated, 153
Lacunæ, 67
Lamellæ, 269
Lamina, 16, 130, 132, 142
Lanceolate, 157, 217
Large spores, 341, 430, 431
Lateral dehiscence, 286
— flowers, 186
— style, 266
Latex, 54
Latex-sacs, 54
Laticiferous vessels, 50, 53, 387
Lattice-cells, 53, 97
Layering, 111
Leaf defined, 16, 129
Leaf-arrangement, 137
Leaf-buds, 16, 98
Leaf-development, 409
Leaflets, 148
Leaf-stalk, 16, 130, 165
Leafy bracts, 177
Leaves of acotyledonous plants, 175
— — dicotyledonous plants, 175
— — monocotyledonous plants, 175

LEG

Legitimate fertilisation, 442
Legume, 288
Lenticels, 86
Liber, 85, 87
Liber-cells, 49
Lichenes, 361
Lichens, 361
Life of the plant, 409, 452
Ligulate, 223
Ligule, 168
Limb, 211, 220
Linear, 157, 159, 217, 235
Linear-lanceolate, 159
Linguiform, 161
Lirellæ, 362
Lithocysts, 35
Liverworts, 9, 346, 428
Lobes of leaves, 150, 230, 269
Loculi, 230, 259
Loculicidal, 280, 281
Locusta, 182, 189
Lodiculæ, 182
Lomentaceous, 296
Lomentum, 289
Longitudinal dehiscence, 236
— system, 55, 70
Luminosity of plants, 453
Lycopodiaceæ, 341, 430
Lycopodium, 342
Lyrate, 153
Lyrately pinnate, 163
Lyre-shaped, 153

MACE, 315
Macropodous, 320
Macrosporangia, 339, 341, 430, 431
Macrospores, 339, 341, 342, 430, 432
Male, 22, 427
— conceptacles, 374
— apparatus, 433
Malting of barley, 449
Marcescent, 216, 226
Marchantia, 9, 381
Marginal placenta, 274
Margins of leaves, 130, 149
Marginal, 263
Marginate, 313
Marsilea, 338, 340, 431, 432
Marsileaceæ, 338, 431
Masked, 223
Mealy albumen, 318
Median prolification, 330
Medulla, 75, 76, 394
Medullary rays, 71, 75
— — functions of, 395

MUL

Medullary rays, secondary, 83
— sheath, 75, 77
Megaspores, 339, 430, 432
Membranous, 213
Mericarp, 282, 297
Merismatic, 378
Meristem, 82, 378
Mesocarp, 275
Mesophyll, 134
Mesothecium, 233
Metabolism, 421
Metamorphosis, 330
— ascending, 330
— descending, 330
— direct, 330
— retrograde, 330
Metastasis, 403, 421
Micropyle, 305, 307, 308
Microsporangia, 341, 342, 430
Microspores, 339, 341, 342, 430, 431
Midrib, 143
Mixed inflorescence, 203
Monadelphous, 241
Monandrous, 238
Moniliform hairs, 61
Monochasial, 201
Monochlamydeous, 19
Monocotyledones, 14, 319
Monocotyledonous embryo, 319
— germination, 450
— leaves, 175
— roots, 124
— stem, 75, 88, 91
Monœcious, 226, 342, 346
Monogynous, 256
Monomerous, 261
Monopetalous, 220, 221, 222
Monopodial branching, 104
Monosepalous, 210
Monothalamic, 300
Monstrosities, 329
Morphological botany, 2, 6
Morphology, 6
— general, 6, 326
Mosses, 9, 342, 429
Mother cells, 243
Movements in cells, 384
— of plants, 455
— — — not periodical, 458, 462
— — — periodical, 456, 461
— of protoplasm, 384
Mucilaginous albumen, 318
Mucor, 7
Mucronate, 157
Mules, 443
Multifoliate, 164
Multijugate, 163

Multiple fruits, 300
Muriform parenchyma, 47, 83
Musci, 342, 429
Mushrooms, 350
Mycelium, 354

NAKED bud, 100
— bulb, 114
— flower, 20
— mouthed, 346
— nucleus, 306
— ovule, 302
Napiform root, 129
Natural history, 1
Nature of carpel, 251
— — cell, 24
Neck, 120
Neck-cell, 435
Necklace-shaped, 61
Nectariferous glands, 66
Needle-shaped, 157
Negative geotropism, 459
— heliotropism, 459
Nervation, 143
Nerves, 131
Netted-veined, 145
Neuter, 226
Nitellæ, 386, 428
Node, 129
Nodes, 13
Nodulose root, 128
Non-adherent, 213
Non-articulated, 130
Non-essential, 19
Non-periodical movements, 458, 462
Normal buds, 105
Nostoc, 368
Nucleoli, 27
Nucleus, 27, 32, 305, 316, 377
— of seed, 23, 312
— — starch, 32
Nuculanium, 299
Nucule, 365, 367, 427
Number of ovules, 303
— — stamens, 238
Nursing leaves, 136
Nut, 298

OBCORDATE, 159
Oblique leaf, 157
Oblong, 37, 158, 217, 235
Obovate, 158
Obsolete, 213
Obtuse, 155
Obvolute, 142, 323
Ochrea, 170
Odours of plants, 463
Œdogonium, 382
Oily albumen, 318
Oogonia, 352, 360, 372
Oophoridia, 430
Oosphere, 352, 373, 435
Oosporangia, 430
Oospore, 352, 373
Open vascular bundles, 72
Opercular, 238
Operculate, 215
Operculum, 345
Opposite leaves, 138
— stipules, 169
Orbicular, 159
Organic constituents, 411
— compounds, 411
— creation, 1
Organography, 2, 5, 6
Organs of nutrition, 14, 15, 68, 376
— — reproduction, 14, 15, 17, 176, 226
Origin of placenta, 265
— — stomata, 389
Orthotropous, 308
Oscillatoria, 6, 29
Osmose, 383
Ostiole, 364
Outline of leaves, 157
Oval, 37, 157, 235
— parenchyma, 45
Ovary, 21, 250, 260
— compound, 260
— simple, 261
Ovate, 158, 217
Ovate-lanceolate, 159
Ovulary spore, 339, 431
Ovule, 21, 302

PALÆONTOLOGICAL botany, 2
Palate, 223
Paleæ, 181, 182, 190
Pales, 182, 190
Palisade parenchyma, 134
Palmate, 153, 165
Palmated root, 127
Palmately cleft, 153
— veined, 145, 161, 163
Palmatifid, 152
Palmatipartite, 153
Palmatisected, 153
Panduriform, 153
Panicle, 192
Panicled corymb, 192

Panicled cyme, 199
Papilionaceous, 219
Papulæ, 64
Pappose, 213
Pappus, 213
Parallel venation, 146
Parallel-veined, 145
Paraphyses, 343, 356, 360, 363, 373
Parasites, 122
Parenchyma, 45
— of leaves, 131, 134
— functions of, 377
— varieties of, 45
Parenchymatous cells, 39, 45, 376
— system, 55, 69, 85
Parent cells, 243
— — special, 244
Parietal cell-formation, 378
— placenta, 263, 264
Paripinnate, 163
Partial dehiscence, 294
— involucre, 179
— petiole, 148, 166
— umbel, 195
Partite, 151, 211, 220, 267
Partitions, 151, 259
Parts of the anther, 230
— — — flower, 204
— — — leaf, 129
Pectinate, 153
Pedate, 165
Pedatifid, 154
Pedatipartite, 154
Pedatisected, 154
Pedicel, 18, 183
Peduncle, 17, 182
Peltate hairs, 62
— leaves, 137
— ovule, 304
Pendulous, 229, 304
Penicillium, 7
Pepo, 299
Pepperworts, 338, 431
Perfoliate, 137
Perianth, 19, 208
Periblem, 117
Pericarp, 22, 275
— dehiscent, 294
— indehiscent, 293
Perichætial, 342
Periderm, 85, 86
Perigone, 342, 348
Perigonial, 342
Perigynous, 239, 250
Periodical movements, 456, 461
Peripheral, 349
Peripherical, 325
Perisperm, 316, 317
Peristome, 345
Perithecia, 358
Permanent stems, 109
— tissue, 82
Persistent, 130, 178, 185, 215, 226, 266
Personate, 223
Petaloid, 19, 208, 213, 228, 267
Petals, 18, 216, 328
Petiolate, 137
Petiole, 16, 130, 131, 165
Petiolule, 148, 166
Peziza, 360
Phænogamous, 11
Phanerogamous, 11
Phelloderm, 85
Phelloderma, 86
Phellogen, 87
Phloëm, 72, 85
Phragmata, 259
Phycomycetes, 350
Phyllaries, 179
Phylloclade, 184
Phyllocyanin, 29, 406
Phyllode, 173
Phylloid peduncle, 184
Phyllome, 16, 129
Phyllotaxis, 137
Phylloxanthein, 406
Phylloxanthin, 29, 406
Physiological botany, 2, 376
Physiology, 376
— of the elementary structures, 376
— — — organs of nutrition, 390
— — — organs of reproduction, 424
— — — root, 390
Phytons, 101
Pileorhiza, 117, 393, 437
Pileus, 355
Pilose, 213, 214
Pilularia, 340, 432
Pinnæ, 163
Pinnate, 162
— with an odd leaflet, 163
Pinnately veined, 145, 161
Pinnatifid, 152
Pinnatipartite, 152
Pinnatisected, 152
Pinnules, 163
Pistil, 20, 250
Pistillate, 22
Pistillidia, 339, 342, 346, 428, 431
Pitchers, 173
Pith, 70, 75, 76
— functions of, 394

Pitted cells, 42
— vessels, 50
Placenta, 21, 250, 253, 263
Placentation, 263
Placentiferous, 284
Plant in action, 415
Plants, odours of, 463
Plaited, 141, 206
Plerome, 117
Plicate, 141, 206
Plumose, 213
Plumule, 13, 319, 321
Pod, 288
Podetium, 362
Podium, 104
Pollen, 20, 243, 433
— cells, 244, 248
— development of, 243
— sporangia, 430
— spores, 339, 431
— structure of, 246
Pollination, 439
Pollinia, 245
Polyadelphous, 241
Polycotyledonous, 322
Polygamous, 227
Polygonal cell, 37
Polyhedral parenchyma, 46
Polymerous, 261
Polypetalous, 218
Polysepalous, 210
Polythalamic, 300
Pome, 299
Pore, 247, 364
Porous cells, 42
— dehiscence, 237, 279, 286
Position of ovules, 303
— — stamens, 238
Positive geotropism, 459
— heliotropism, 459
Præfloration, 204
Præfoliation, 140
Præmorse leaf, 156
— root, 110
Prickles, 63
Primary meristem, 393
— root, 117
Primine, 307, 438
Primordial cell, 24, 306
— leaves, 136, 450
— utricle, 25, 27
Prismatic cell, 39
Procambium, 117, 120
Process of germination, 449
Production of chlorophyll, 454
— — hybrids, 442
Pro-embryo, 333, 428, 437, 441
Proliferous, 106
Prosenchyma, 48
— functions of, 387
Prosenchymatous cells, 39, 45
Prostrate, 107
Proteid grains, 36
Proteine crystals, 36
Prothallium, 333, 336, 337, 346, 429
Prothallus, 333
Protococcus, 6, 376
Protonema, 346, 350, 429
Protoplasm, 24, 26, 377
— movements of, 384
Protruding, 242
Pseud-axis, 105
Pseudocarp, 300
Pseudo-embryo, 431
Pseudo-parenchyma, 47
Puccinia, 352, 354
Pulvinus, 166
Punctum vegetationis, 89, 393, 396
Putamen, 275
Pycnidia, 363
Pyramidal leaf, 161
Pyxis, 294

QUADRIFOLIATE, 164
Quadrilocular, 230
Quadrinate, 164
Quinate, 164
Quincuncial, 206
Quinquefoliate, 164

RACEME, 191
Racemose, 105
— corymb, 192
— cyme, 199
Rachis, 148, 166, 183
Radiated veined, 145, 161
Radical leaves, 136
— peduncle, 184
Radicle, 13, 319, 321
Ramal leaves, 136
Ramenta, 63
Ramentaceous hairs, 63
Ramification, 98, 103
Raphe, 309
Raphides, 34
Receptacle, 16, 183, 271, 354, 373
Receptacles of secretion, 67, 390
Reclinate, 140, 323
Recurved, 229
Reduplicate, 205
Reflexed, 210, 217
Regular, 210, 212,

Regular buds, 105
— corolla, 219, 220, 221
— flower, 347
— parenchyma, 46, 76
Rejuvenescence, 382
Renewal of cell, 382
Reniform, 159
Replum, 260, 284, 296
Reproduction of—
— Acotyledonous plants, 427
— Angiospermia, 437
— Characeæ, 427
— Charas, 427
— Cormophytes, 428
— Cotyledonous plants, 433
— Cryptogamous plants, 427
— Equisetaceæ, 432
— Filices, 432
— Gymnospermia, 434
— Hepaticaceæ, 428
— Lycopodiaceæ, 430
— Marsileaceæ, 431
— Musci, 429
— Phanerogamous plants, 433
— Thallophytes, 427
Reproductive Organs of—
— — Acrogens, 333
— — Algæ, 333
— — Characeæ, 365
— — Cormophytes, 333
— — Cryptogamia, 332
— — Equisetaceæ, 337
— — Filices, 333
— — Fungi, 350
— — Hepaticaceæ, 346
— — Lichenes, 361
— — Lycopodiaceæ, 341
— — Marsileaceæ, 338
— — Musci, 342
— — Thallophytes, 350
Respiration, 4, 402, 421
Reticulated cells, 45
— veined, 145
— vessels, 50, 51
Retinacula, 245
Retrograde metamorphosis, 330
Retroserrate, 149
Retuse, 155
Revolute, 141
Revolving nutation, 456
Rhizoid, 427
Rhizome, 110
Ribbed venation, 145
Ribs, 143
Rind, 71, 88, 90
Ringed cells, 45
Ringent, 222
Ripening of fruits, 446
Rolled leaves, 140, 142
Root, 14, 15, 116, 390
Roots of dicotyledonous plants, 124
— — monocotyledonous plants, 124
— — acotyledonous plants, 125
Root-cap, 117
Root-hairs, 63, 118
Rootlet, 428
Root-pressure, 391, 420
Root-sheath, 451
Rootstock, 110
Rosaceous, 219
Rostellum, 245
Rotate, 221
Rotation, 385
Rounded cell, 37
— leaf, 159
— lobes, 235
Roundish ovate, 159
Round parenchyma, 45
Ruminated, 318
Runcinate, 153
Runner, 110

Saccate, 214, 224
Saccharose, 445
Sagittate, 159, 235
Salver-shaped, 221
Salvinia, 340, 431, 432
Samara, 294
Sap, 27, 79, 416
Saprophytes, 123
Sapwood, 80
Sarcocarp, 275
Scalariform vessels, 50, 52
Scales, 62, 99, 129, 178, 181
Scaly bracts, 178
— buds, 99
— bulb, 114
Scape, 184
Scars of leaves, 166
— — ferns, 96
Schizocarps, 282
Sclerenchyma, 47, 89, 97
Sclerenchymatous, 41
Sclerotium, 358
Scorpioid cyme, 199, 201
— dichotomy, 105
Scurf, 63
Seaweeds, 368
Secondary axis, 183
— embryo-sacs, 435
— medullary rays, 83
— products, 422
— root, 117, 119, 125

Secretion, 403
— receptacles of, 67
Sected, 151
Secund, 200
Secundine, 307, 438
Seed, 11, 22, 275, 302, 310, 446
Seed, vitality of, 446
Segment cell, 396
Segments, 151
Selecting power of roots, 392
Sepals, 18, 208, 327
Septemfoliate, 164
Septenate, 164
Septicidal, 280
Septifragal, 280, 282
Serrate, 149
Serrulate, 149
Sessile anther, 227
— glands, 63, 64
— leaves, 17, 131, 137
— ovary, 250, 261
— ovule, 302
— seed, 310
Seta, 344
Setæ, 33
Sexuality of plants, 426
Sharp-pointed, 156
Sheath, 167
Sheathing, 137
Shield-like, 62
Shield-cells, 365
Shrubs, 108
Sieve-cells, 53
Sieve-tubes, 50, 52
Sieve-vessels, 50, 52, 387
Silicula, 296
Siliqua, 295
Siliquæform capsule, 296
Silver-grain, 84
Simple corymb, 192
— fruits, 274, 288
— gynœcium, 256
— hairs, 60
— leaves, 131, 148, 149
— ovary, 261
— pappus, 213
— petiole, 166
— pistil, 250
— style, 267
Simultaneous vascular bundles, 74, 95
Sinuous, 235
Size of cells, 40
— — dicotyledonous trees, 82
Skeleton leaves, 134
Small spores, 339, 341, 430, 431
Soboles, 111
Solitary axillary flower, 187
Solitary terminal flower, 195
Soredia, 365
Sori, 334
Sorosis, 301
Sources of food, 410
Spadix, 180, 189
Spathaceous bracts, 181
Spathe, 180
Spathellæ, 180
Spathulate, 158
Special functions of the stem, 394
— mother cells, 244
— physiology, 376
Specific identity, 102
Spermatia, 354, 364
Spermatophores, 364
Spermatozoids, 367
Sperm-cells, 336, 343, 432
Spermogonia, 354, 363
Sphacelia, 357
Sphæraphides, 35
Sphalerocarpium, 301
Spherical cell, 37
Spike, 188
Spiked cyme, 199
Spikelet, 182, 189
Spine, 102
Spines of leaves, 172
Spiral cells, 45
— æstivation, 206
— vernation, 142
— vessels, 50, 51, 95
Spirogyra, 29, 369, 382
Spongiform parenchyma, 46
Spongiole, 121
Sporangium, 8, 334, 339, 341, 344, 348, 431
Spore-producing structure, 354
Spores, 7, 11, 332
Sporocarp, 338
Spur, 224
Spurious dissepiment, 259
— fruit, 274, 300
Spurred, 214, 224
Squamæ, 178
Squamous, 178
Squamulæ, 182
Stalk, 355
Stalked, 63, 137, 214, 261, 310
Stalklets, 148, 166
Stamens, 20, 227, 238, 328
Staminate, 22
Staminodes, 227
Standard, 219
Starch, 4, 29
— granules, 31
— — compound, 33
— nucleus, 32

Starchy albumen, 318
Stellate hairs, 61
Stellate cells, 38
— parenchyma, 46
Stem, 14, 15, 394
— defined, 68
Stemless, 69
Sterigmata, 364
Sterile, 227
Stigma, 21, 250, 255, 268
Sting, 65
Stipe, 355
Stipellate, 169
Stipels, 169
Stipitate, 261
Stipular, 130
Stipulate, 169
Stipules, 17, 168
Stolon, 110
Stoloniferous, 111
Stoma, 58, 345
Stomata, 57, 388
Stone, 275
Storing of nutriment by roots, 393
Strap-shaped, 223
Strobile, 191, 301
Strobilus, 191, 301
Strophioles, 315
Structural botany, 2, 6
Structure of anther, 232
— — carpel, 252
— — cell-wall, 41
— — ovule, 305
— — pollen, 246
— — seed, 312
— — stem, 69
Struma,
Style, 21, 251, 253, 266
Stylopodium, 249
Stylospores, 363
Sub-hybrids, 443
Sub-hymenial layer, 356
Submersed leaves, 131
— — structure of, 135
Sub-rotund, 159
Subterranean stems, 111
Subulate, 157
Succulent, 129
Summit growers, 72
Superficial placenta, 265
Superior calyx, 213, 262
— fruit, 275
— ovary, 213, 262
— radicle, 326
— syncarpous fruits, 293
Superposed, 304
Supervolute, 142
Supra-axillary, 130
Suspended ovule, 304
Suspensor, 437, 441
Sutural, 236, 280
Sutures, 232, 276
Swarm spore, 352
Syconus, 302
Sympodial, 104
Sympodium, 105
Synantherous, 240
Syncarpous fruits, 274, 293
— pistil, 256
Syngenesious, 240
Systematic botany, 2

TABULAR cells, 38
— parenchyma, 46
Tailed fruit, 291
Taper-pointed, 157
Tap-root, 124
Tegmen, 312, 314
Tegmenta, 99
Tela-contexta, 47
Teleutospores, 354
Tendril, 103
Tendrils of leaves, 172
Terminal buds, 91
— inflorescence, 186, 187, 195, 196
Ternate, 164
Tertiary axis, 183
Testa, 312
Tetradynamous, 243
Tetramerous, 261
Tetrandrous, 238
Thalamium, 362
Thalamus, 18, 271
Thallogens, 8
Thallome, 8
Thallophytes, 8, 11
Thallus, 8
Thecæ, 334, 337
Theoretical structure of the flower, 326
Thorn, 102
Throat, 211, 220
Thyrse, 193
Thyrsus, 193
Tigelle, 13, 319, 321
Tigellum, 13
Toothed, 149, 218, 220, 228
Torus, 271
Tracheïdes, 45
Trama, 356
Transpiration, 397
Transverse dehiscence, 236, 279, 285, 294

Transverse ovule, 309
Tree, 108
Triadelphous, 241
Triandrous, 238
Trichomes, 60
Tricoccous, 282
Tricostate, 146
Trifid, 151, 267, 269
Trifoliate, 164
Trigynous, 256
Trijugate, 163
Trilobate, 269
Trilocular, 259
Trimerous, 261
Trimorphic, 442
Tripartite, 151, 267
Tripinnate, 163
Tripinnatifid, 152
Tripinnatipartite, 152
Tripinnatisected, 152
Trisected, 151
Triternate, 165
True arillus, 315
— raphides, 35
— root, 117, 124
Truncate, 156
Trunk, 108
Tube, 211, 220
Tuber, 112
Tuberculated root, 126
Tubercule, 126
Tubular, 212, 217, 221
— leaf, 161
Tuft, 139
Tufted leaves, 139
— root, 127
Tunic, 114
Tunicated bulb, 114
Twigs, 103
Twining, 108
Twisted æstivation, 206
— vernation, 142
Tyloses, 51
Tympanum, 346

Umbel, 194
Umbelliferous, 195
Umbellule, 195
Uncinate, 61
Undershrub, 109
Undulated, 150
Unequal leaf, 157
Unequally pinnate, 163
Unguiculate, 217
Unguis, 217
Unijugate, 163
Unilateral, 201
Unilocular, 230, 274
Union of stamens, 240
Uniparous, 201
Unisexual, 22, 226
Urceolate, 212, 221
Uredo-fruits, 354
Uredo-spores, 354
Urn-shaped, 221
Utricular vessels, 50

Vacuoles, 25, 28
Vagina, 167
Vaginule, 344, 349
Valvate, 142, 205
Valves, 277
Valvular dehiscence, 238, 279
— æstivation, 205, 206
Varieties of bracts, 178
— — venation, 145
Vascular bundles, 72
— — closed, 74
— — definite, 74
— — indefinite, 72
— — progressive, 72
— — simultaneous, 74
— plants, 9
Vaucheria, 371
Vegetable histology, 2
— respiration, 401
Veil, 356
Veins, 131, 143
Veinless, 143
Veinlets, 143
Velamen radicum, 122
Venation, 143
— of acotyledonous leaves, 1
— varieties of, 143
Ventral suture, 251
Vernation, 139, 204
Versatile, 234
Verticil, 138
Verticillaster, 202
Verticillate, 138
Vesicles, germinal, 305
Vesicular vessels, 50, 54, 387
Vessels, 11, 49
— annular, 95
— functions of, 387
— spiral, 95
Vexillary, 206, 207
Vexillum, 207, 219
Vital force, 26
Vitality of seeds, 447
Vitellus, 314
Vittæ, 68
Volva, 356

WAV ZYG

Wavy, 150
Wedge-shaped, 158
Wheel-shaped, 221
Whorl, 138
Whorled, 138, 187
Wing, 168, 220
Winged, 168, 313
Wood, formation of, 395
— functions of, 394
— structure of, 70, 75
Woody fibre, 48
Woody tissue, 48, 49
— — of the liber, 49

Xanthic, 425
Xylem, 72, 77

Zoogonidia, 372
Zoospores, 352, 372
Zygospore, 370, 382

LONDON: PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
AND PARLIAMENT STREET

BY THE SAME AUTHOR.

A MANUAL of BOTANY; including the Structure, Classification, Properties, Uses, and Functions of Plants. Fourth Edition, with 1,185 Engravings, 870 pp. crown 8vo. 15*s.*

'Amongst all these rivals, "Bentley" holds its place as the botanical text-book which enters into the fullest details of that side of the study which comes most home to the medical, and especially to the pharmaceutical student. In no other elementary work of the kind is there anything like the amount of information respecting the pharmaceutical and other economical products obtained from the various families of the vegetable kingdom.

'The present edition indicates the great advance which botanical science has made during recent years. The volume is considerably increased in size, and some parts have been to a great extent re-written, the results of the most recent researches being incorporated. The portions relating to the elementary structure of vegetable tissues, to the physiology of plants, and to the modes of reproduction in flowerless plants, are those in which there is most novelty; while the publication, since the third edition, of such works as Flückiger and Hanbury's "Pharmacographia" and Bentley and Trimen's "Medicinal Plants" has rendered necessary a large amount of alteration and addition in the part which treats of the properties and uses of plants. A great improvement is the introduction of many new woodcuts, especially in the portions relating to minute structure, physiology, and to the life history of the cryptogamia, from Sachs, Pringsheim, Darwin, and others; and as a minor point, we may note the advantage, not a small one in a text-book, of the leaves being already cut to the reader's hand.'

PHARMACEUTICAL JOURNAL.

'A model of careful, conscientious, clear, and exhaustive description, and one of the best of Churchill's admirable series of manuals.'—BRITISH MEDICAL JOURNAL.

'Professor Bentley's manual contains an immense amount of valuable information, and is a perfect marvel of literary condensation.'—VETERINARIAN.

J. & A. CHURCHILL, 11 New Burlington Street.

MEDICINAL PLANTS: being Descriptions with original Figures of the Principal Plants employed in Medicine, and an Account of their Properties and Uses. By Robert Bentley, F.L.S., M.R.C.S., Professor of Botany in King's College and to the Pharmaceutical Society, and Henry Trimen, M.B., F.L.S., late of the British Museum, and Lecturer on Botany at St. Mary's Hospital Medical School. In 4 vols. Large 8vo. with 306 Coloured Plates, bound in half morocco, gilt edges, £11. 11*s.*

'One of the most valuable contributions ever made to the scientific study of materia medica, and is indispensable to every teacher and earnest student of that branch of medical knowledge.'—Dublin Medical Journal.

'It is an invaluable book as a work of reference, and forms a noble contribution to botanical and medical science.'
Edinburgh Medical Journal.

'Both in letterpress and illustration this splendid book is singularly complete.'—British Medical Journal.

'It is not often that a reviewer can rise from a critical examination of a *livre de luxe* with such an unmixed feeling of satisfaction as in the case of these handsome volumes.'
Nature.

'A work which from all points of view is a credit to the scientific literature of the day.'—Lancet.

'To the student this will be a very valuable work of reference, especially in preparing for his examinations; while it will form a handsome and valuable addition to the library of every medical man.—Medical Press and Circular.

J. & A. CHURCHILL, 11 New Burlington Street.

[CATALOGUE C]

LONDON, *April*, 1883.

J. & A. CHURCHILL'S

MEDICAL CLASS BOOKS.

ANATOMY.

BRAUNE.—An Atlas of Topographical Anatomy, after Plane Sections of Frozen Bodies. By WILHELM BRAUNE, Professor of Anatomy in the University of Leipzig. Translated by EDWARD BELLAMY, F.R.C.S., and Member of the Board of Examiners; Surgeon to Charing Cross Hospital, and Lecturer on Anatomy in its School. With 34 Photo-lithographic Plates and 46 Woodcuts. Large Imp. 8vo, 40s.

FLOWER.—Diagrams of the Nerves of the Human Body, exhibiting their Origin, Divisions, and Connexions, with their Distribution to the various Regions of the Cutaneous Surface, and to all the Muscles. By WILLIAM H. FLOWER, F.R.C.S., F.R.S., Hunterian Professor of Comparative Anatomy, and Conservator of the Museum, Royal College of Surgeons. Third Edition, containing 6 Plates. Royal 4to, 12s.

GODLEE.—An Atlas of Human Anatomy: illustrating most of the ordinary Dissections and many not usually practised by the Student. By RICKMAN J. GODLEE, M.S., F.R.C.S., Assistant-Surgeon to University College Hospital, and Senior Demonstrator of Anatomy in University College. With 48 Imp. 4to Coloured Plates, containing 112 Figures, and a Volume of Explanatory Text, with many Engravings. 8vo, £4 14s. 6d.

HEATH.—Practical Anatomy: a Manual of Dissections. By CHRISTOPHER HEATH, F.R.C.S., Holme Professor of Clinical Surgery in University College and Surgeon to the Hospital. Fifth Edition. With 24 Coloured Plates and 269 Engravings. Crown 8vo, 15s.

ANATOMY—*continued.*

HOLDEN.—A Manual of the Dissection of the Human Body. By Luther Holden, F.R.C.S., Consulting-Surgeon to St. Bartholomew's Hospital. Fourth Edition. Revised by the Author and John Langton, F.R.C.S., Surgeon and Lecturer on Anatomy at St. Bartholomew's Hospital. With Engravings. 8vo, 16s.

By the same Author.

Human Osteology: comprising a Description of the Bones, with Delineations of the Attachments of the Muscles, the General and Microscopical Structure of Bone and its Development. Sixth Edition, revised by the Author and James Shuter, F.R.C.S., Assistant-Surgeon to St. Bartholomew's Hospital. With 61 Lithographic Plates and 89 Engravings. Royal 8vo, 16s.

ALSO,

Landmarks, Medical and Surgical. Third Edition. 8vo, 3s. 6d.

MORRIS.—The Anatomy of the Joints of Man. By Henry Morris, M.A., F.R.C.S., Surgeon to, and Lecturer on Anatomy and Practical Surgery at, the Middlesex Hospital. With 44 Plates (19 Coloured) and Engravings. 8vo, 16s.

The Anatomical Remembrancer; or, Complete Pocket Anatomist. Eighth Edition. 32mo, 3s. 6d.

WAGSTAFFE.—The Student's Guide to Human Osteology. By Wm. Warwick Wagstaffe, F.R.C.S., late Assistant-Surgeon to, and Lecturer on Anatomy at, St. Thomas's Hospital. With 23 Plates and 66 Engravings. Fcap. 8vo, 10s. 6d.

WILSON — BUCHANAN — CLARK.— Wilson's Anatomist's Vade-Mecum: a System of Human Anatomy. Tenth Edition, by George Buchanan, Professor of Clinical Surgery in the University of Glasgow, and Henry E. Clark, M.R.C.S., Lecturer on Anatomy in the Glasgow Royal Infirmary School of Medicine. With 450 Engravings, including 26 Coloured Plates. Crown 8vo, 18s.

BOTANY.

BENTLEY.—A Manual of Botany. By Robert Bentley, F.L.S., M.R.C.S., Professor of Botany in King's College and to the Pharmaceutical Society. With 1185 Engravings. Fourth Edition. Crown 8vo, 15s.

BENTLEY AND TRIMEN.—Medicinal Plants: being descriptions, with original Figures, of the Principal Plants employed in Medicine, and an account of their Properties and Uses. By Robert Bentley, F.L.S., and Henry Trimen, M.B., F.L.S. In 4 Vols., large 8vo, with 306 Coloured Plates, bound in half morocco, gilt edges, £11 11s.

CHEMISTRY.

BERNAYS.—Notes for Students in Chemistry; being a Syllabus of Chemistry compiled mainly from the Manuals of Fownes-Watts, Miller, Wurz, and Schorlemmer. By Albert J. Bernays, Ph.D., Professor of Chemistry at St. Thomas's Hospital. Sixth Edition. Fcap. 8vo, 3s. 6d.

By the same Author.

Skeleton Notes on Analytical Chemistry. for Students in Medicine. Fcap. 8vo, 2s. 6d.

BLOXAM.—Chemistry, Inorganic and Organic; with Experiments. By Charles L. Bloxam, Professor of Chemistry in King's College. Fifth Edition. With nearly 300 Engravings. 8vo, 16s.

By the same Author.

Laboratory Teaching; or, Progressive Exercises in Practical Chemistry. Fourth Edition. With 83 Engravings. Crown 8vo, 5s. 6d.

CHEMISTRY—*continued.*

BOWMAN AND BLOXAM.—**Practical Chemistry,** including Analysis. By John E. Bowman, formerly Professor of Practical Chemistry in King's College, and Charles L. Bloxam, Professor of Chemistry in King's College. With 98 Engravings. Seventh Edition. Fcap. 8vo, 6s. 6d.

BROWN.—**Practical Chemistry: Analytical** Tables and Exercises for Students. By J. Campbell Brown, D.Sc. Lond., Professor of Chemistry in University College, Liverpool. Second Edition. 8vo, 2s. 6d.

CLOWES.—**Practical Chemistry and Qualitative** Inorganic Analysis. An Elementary Treatise, specially adapted for use in the Laboratories of Schools and Colleges, and by Beginners. By Frank Clowes, D.Sc., Professor of Chemistry in University College, Nottingham. Third Edition. With 47 Engravings. Post 8vo, 7s. 6d.

FOWNES AND WATTS.—**Physical and Inorganic** Chemistry. Twelfth Edition. By George Fownes, F.R.S., and Henry Watts, B.A., F.R.S. With 154 Engravings, and Coloured Plate of Spectra. Crown 8vo, 8s. 6d.

By the same Authors.

Chemistry of Carbon - Compounds, or Organic Chemistry. Twelfth Edition. With Engravings. Crown 8vo, 10s.

LUFF.—**An Introduction to the Study of Chemistry.** Specially designed for Medical and Pharmaceutical Students. By A. P. Luff, F.I.C., F.C.S., Lecturer on Chemistry in the Central School of Chemistry and Pharmacy. Crown 8vo, 2s. 6d.

TIDY.—**A Handbook of Modern Chemistry,** Inorganic and Organic. By C. Meymott Tidy, M.B., Professor of Chemistry and Medical Jurisprudence at the London Hospital. 8vo, 16s.

VACHER.—**A Primer of Chemistry, including** Analysis. By Arthur Vacher. 18mo, 1s.

CHEMISTRY—*continued.*

VALENTIN.—**Introduction to Inorganic Chemistry.** By WILLIAM G. VALENTIN, F.C.S. Third Edition. With 82 Engravings. 8vo, 6s. 6d.

By the same Author.

A Course of Qualitative Chemical Analysis. Fifth Edition. By W. R. HODGKINSON, Ph.D. (Würzburg), Demonstrator of Practical Chemistry in the Science Training Schools. With Engravings. 8vo, 7s. 6d.

ALSO,

Chemical Tables for the Lecture-room and Laboratory. In Five large Sheets, 5s. 6d.

CHILDREN, DISEASES OF.

DAY.—**A Treatise on the Diseases of Children.** For Practitioners and Students. By WILLIAM H. DAY, M.D., Physician to the Samaritan Hospital for Women and Children. Crown 8vo, 12s. 6d.

ELLIS.—**A Practical Manual of the Diseases of Children.** By EDWARD ELLIS, M.D., late Senior Physician to the Victoria Hospital for Sick Children. With a Formulary. Fourth Edition. Crown 8vo, 10s.

SMITH.—**Clinical Studies of Disease in Children.** By EUSTACE SMITH, M.D., F.R.C.P., Physician to H.M. the King of the Belgians, and to the East London Hospital for Children. Second Edition. Post 8vo. [*In preparation.*

By the same Author.

On the Wasting Diseases of Infants and Children. Third Edition. Post 8vo, 8s. 6d.

STEINER.—**Compendium of Children's Diseases;** a Handbook for Practitioners and Students. By JOHANN STEINER, M.D. Translated by LAWSON TAIT, F.R.C.S., Surgeon to the Birmingham Hospital for Women, &c. 8vo, 12s. 6d.

DENTISTRY.

SEWILL.—**The Student's Guide to Dental Anatomy and Surgery.** By HENRY E. SEWILL, M.R.C.S., L.D.S., late Dental Surgeon to the West London Hospital. Second Edition. With 78 Engravings. Fcap. 8vo, 5s. 6d.

STOCKEN.—**Elements of Dental Materia Medica** and Therapeutics, with Pharmacopœia. By JAMES STOCKEN, L.D.S.R.C.S., late Lecturer on Dental Materia Medica and Therapeutics and Dental Surgeon to the National Dental Hospital, assisted by THOMAS GADDES, L.D.S. Eng. and Edin. Third Edition. Fcap. 8vo, 7s. 6d.

TAFT.—**A Practical Treatise on Operative** Dentistry. By JONATHAN TAFT, D.D.S., Professor of Operative Surgery in the Ohio College of Dental Surgery. Third Edition. With 134 Engravings. 8vo, 18s.

TOMES (C. S.).—**Manual of Dental Anatomy,** Human and Comparative. By CHARLES S. TOMES, M.A., F.R.S. Second Edition. With 191 Engravings. Crown 8vo, 12s. 6d.

TOMES (J. and C. S.).—**A Manual of Dental** Surgery. By JOHN TOMES, M.R.C.S., F.R.S., and CHARLES S. TOMES, M.A., M.R.C.S., F.R.S.; Lecturer on Anatomy and Physiology at the Dental Hospital of London. Second Edition. With 262 Engravings. Fcap. 8vo, 14s.

EAR, DISEASES OF.

BURNETT.—**The Ear: its Anatomy, Physiology,** and Diseases. A Practical Treatise for the Use of Medical Students and Practitioners. By CHARLES H. BURNETT, M.D., Aural Surgeon to the Presbyterian Hospital, Philadelphia. With 87 Engravings. 8vo, 18s.

DALBY.—**On Diseases and Injuries of the Ear.** By WILLIAM B. DALBY, F.R.C.S., Aural Surgeon to, and Lecturer on Aural Surgery at, St. George's Hospital. Second Edition. With Engravings. Fcap. 8vo, 6s. 6d.

EAR, DISEASES OF—*continued.*

JONES.—A Practical Treatise on Aural Surgery. By H. MACNAUGHTON JONES, M.D., Professor of the Queen's University in Ireland, Surgeon to the Cork Ophthalmic and Aural Hospital. Second Edition. With 63 Engravings. Crown 8vo, 8s. 6d.

By the same Author.

Atlas of the Diseases of the Membrana Tympani. In Coloured Plates, containing 59 Figures. With Explanatory Text. Crown 4to, 21s.

FORENSIC MEDICINE.

OGSTON.—Lectures on Medical Jurisprudence. By FRANCIS OGSTON, M.D., Professor of Medical Jurisprudence and Medical Logic in the University of Aberdeen. Edited by FRANCIS OGSTON, Jun., M.D., Assistant to the Professor of Medical Jurisprudence and Lecturer on Practical Toxicology in the University of Aberdeen. With 12 Plates. 8vo, 18s.

TAYLOR.—The Principles and Practice of Medical Jurisprudence. By ALFRED S. TAYLOR, M.D., F.R.S. Third Edition, revised by THOMAS STEVENSON, M.D., F.R.C.P., Lecturer on Chemistry and Medical Jurisprudence at Guy's Hospital; Examiner in Chemistry at the Royal College of Physicians; Official Analyst to the Home Office. With 188 Engravings. 2 Vols. 8vo, 31s. 6d.

By the same Author.

A Manual of Medical Jurisprudence. Tenth Edition. With 55 Engravings. Crown 8vo, 14s.

ALSO,

On Poisons, in relation to Medical Jurisprudence and Medicine. Third Edition. With 104 Engravings. Crown 8vo, 16s.

TIDY AND WOODMAN.—A Handy-Book of Forensic Medicine and Toxicology. By C. MEYMOTT TIDY, M.B.; and W. BATHURST WOODMAN, M.D., F.R.C.P. With 8 Lithographic Plates and 116 Wood Engravings. 8vo, 31s. 6d.

HYGIENE.

PARKES.—A Manual of Practical Hygiene. By Edmund A. Parkes, M.D., F.R.S. Sixth Edition by F. De Chaumont, M.D., F.R.S., Professor of Military Hygiene in the Army Medical School. With 9 Plates and 103 Engravings. 8vo, 18s.

WILSON.—A Handbook of Hygiene and Sanitary Science. By George Wilson, M.A., M.D., Medical Officer of Health for Mid Warwickshire. Fourth Edition. With Engravings. Crown 8vo, 10s. 6d.

MATERIA MEDICA AND THERAPEUTICS.

BINZ AND SPARKS.—The Elements of Therapeutics: a Clinical Guide to the Action of Medicines. By C. Binz, M.D., Professor of Pharmacology in the University of Bonn. Translated and Edited with Additions, in conformity with the British and American Pharmacopœias, by Edward I. Sparks, M.A., M.B., F.R.C.P. Lond. Crown 8vo, 8s. 6d.

OWEN.—Tables of Materia Medica; comprising the Contents, Doses, Proportional Composition, and Methods of Manufacture of Pharmacopœial Preparations. By Isambard Owen, M.B., M.R.C.P., Lecturer on Materia Medica at St. George's Hospital. Sixth Edition. Crown 8vo. [*In the press.*

ROYLE AND HARLEY.—A Manual of Materia Medica and Therapeutics. By J. Forbes Royle, M.D., F.R.S., and John Harley, M.D., F.R.C.P., Physician to, and Joint Lecturer on Clinical Medicine at, St. Thomas's Hospital. Sixth Edition. With 139 Engravings. Crown 8vo, 15s.

THOROWGOOD.—The Student's Guide to Materia Medica and Therapeutics. By John C. Thorowgood, M.D., F.R.C.P., Lecturer on Materia Medica at the Middlesex Hospital. Second Edition. With Engravings. Fcap. 8vo, 7s.

WARING.—A Manual of Practical Therapeutics. By Edward J. Waring, C.I.E., M.D., F.R.C.P. Third Edition. Fcap. 8vo, 12s. 6d.

MEDICINE.

BARCLAY.—A Manual of Medical Diagnosis. By A. WHYTE BARCLAY, M.D., F.R.C.P., late Physician to, and Lecturer on Medicine at, St. George's Hospital. Third Edition. Fcap. 8vo, 10s. 6d.

CHARTERIS.—The Student's Guide to the Practice of Medicine. By MATTHEW CHARTERIS, M.D., Professor of Materia Medica, University of Glasgow; Physician to the Royal Infirmary. With Engravings on Copper and Wood. Third Edition. Fcap. 8vo, 7s.

FENWICK.—The Student's Guide to Medical Diagnosis. By SAMUEL FENWICK, M.D., F.R.C.P., Physician to the London Hospital. Fifth Edition. With 111 Engravings. Fcap. 8vo, 7s.

By the same Author.

The Student's Outlines of Medical Treatment. Second Edition. Fcap. 8vo, 7s.

FLINT.—Clinical Medicine: a Systematic Treatise on the Diagnosis and Treatment of Disease. By AUSTIN FLINT, M.D., Professor of the Principles and Practice of Medicine, &c., in Bellevue Hospital Medical College. 8vo, 20s.

HALL.—Synopsis of the Diseases of the Larynx, Lungs, and Heart: comprising Dr. Edwards' Tables on the Examination of the Chest. With Alterations and Additions. By F. DE HAVILLAND HALL, M.D., F.R.C.P., Assistant-Physician to the Westminster Hospital. Royal 8vo, 2s. 6d.

SANSOM.—Manual of the Physical Diagnosis of Diseases of the Heart, including the use of the Sphygmograph and Cardiograph. By A. E. SANSOM, M.D., F.R.C.P., Assistant-Physician to the London Hospital. Third Edition. With 47 Woodcuts. Fcap. 8vo, 7s. 6d.

WARNER.—Student's Guide to Medical Case-Taking. By FRANCIS WARNER, M.D., Assistant-Physician to the London Hospital. Fcap. 8vo, 5s.

WEST.—How to Examine the Chest: being a Practical Guide for the Use of Students. By SAMUEL WEST, M.D., M.R.C.P., Physician to the City of London Hospital for Diseases of the Chest, &c. With 42 Engravings. Fcap. 8vo, 6s.

MEDICINE—*continued.*

WHITTAKER.—**Students' Primer on the Urine.** By J. Travis Whittaker, M.D., Clinical Demonstrator at the Royal Infirmary, Glasgow. With Illustrations, and 16 Plates etched on Copper. Post 8vo, 4s. 6d.

MIDWIFERY.

BARNES.—**Lectures on Obstetric Operations,** including the Treatment of Hæmorrhage, and forming a Guide to the Management of Difficult Labour. By Robert Barnes, M.D., F.R.C.P., Obstetric Physician to, and Lecturer on Diseases of Women, &c., at, St. George's Hospital. Third Edition. With 124 Engravings. 8vo, 18s.

CLAY.—**The Complete Handbook of Obstetric** Surgery; or, Short Rules of Practice in every Emergency, from the Simplest to the most formidable Operations connected with the Science of Obstetricy. By Charles Clay, M.D., late Senior Surgeon to, and Lecturer on Midwifery at, St. Mary's Hospital, Manchester. Third Edition. With 91 Engravings. Fcap. 8vo, 6s. 6d.

RAMSBOTHAM.—**The Principles and Practice** of Obstetric Medicine and Surgery. By Francis H. Ramsbotham, M.D., formerly Obstetric Physician to the London Hospital. Fifth Edition. With 120 Plates, forming one thick handsome volume. 8vo, 22s.

REYNOLDS.—**Notes on Midwifery: specially** designed to assist the Student in preparing for Examination. By J. J. Reynolds, M.R.C.S. Fcap. 8vo, 4s.

ROBERTS.—**The Student's Guide to the Practice** of Midwifery. By D. Lloyd Roberts, M.D., F.R.C.P., Physician to St. Mary's Hospital, Manchester. Second Edition. With 111 Engravings. Fcap. 8vo, 7s.

SCHROEDER.—**A Manual of Midwifery; including** the Pathology of Pregnancy and the Puerperal State. By Karl Schroeder, M.D., Professor of Midwifery in the University of Erlangen. Translated by Charles H. Carter, M.D. With Engravings. 8vo, 12s. 6d.

MIDWIFERY—*continued.*

SWAYNE.—Obstetric Aphorisms for the Use of Students commencing Midwifery Practice. By Joseph G. Swayne, M.D., Lecturer on Midwifery at the Bristol School of Medicine. Seventh Edition. With Engravings. Fcap. 8vo, 3s. 6d.

MICROSCOPY.

CARPENTER.—The Microscope and its Revelations. By William B. Carpenter, C.B., M.D., F.R.S. Sixth Edition. With 26 Plates, a Coloured Frontispiece, and more than 500 Engravings. Crown 8vo, 16s.

MARSH.—Microscopical Section-Cutting: a Practical Guide to the Preparation and Mounting of Sections for the Microscope, special prominence being given to the subject of Animal Sections. By Dr. Sylvester Marsh. Second Edition. With 17 Engravings. Fcap. 8vo, 3s. 6d.

MARTIN.—A Manual of Microscopic Mounting By John H. Martin, Member of the Society of Public Analysts, &c. Second Edition. With several Plates and 144 Engravings. 8vo, 7s. 6d.

OPHTHALMOLOGY.

DAGUENET.—A Manual of Ophthalmoscopy for the Use of Students. By Dr. Daguenet. Translated by C. S. Jeaffreson, Surgeon to the Newcastle-on-Tyne Eye Infirmary. Wit Engravings. Fcap. 8vo, 5s.

HIGGENS.—Hints on Ophthalmic Out-Patient Practice. By Charles Higgens, F.R.C.S., Ophthalmic Surgeon to, and Lecturer on Ophthalmology at, Guy's Hospital. Second Edition. Fcap. 8vo, 3s.

JONES.—A Manual of the Principles and Practice of Ophthalmic Medicine and Surgery. By T. Wharton Jones, F.R.C.S., F.R.S., late Ophthalmic Surgeon and Professor of Ophthalmology to University College Hospital. Third Edition. With 9 Coloured Plates and 173 Engravings. Fcap. 8vo, 12s. 6d.

OPHTHALMOLOGY—*continued.*

MACNAMARA.—A Manual of the Diseases of the Eye. By CHARLES MACNAMARA, F.R.C.S., Surgeon to, and Lecturer on Surgery at, Westminster Hospital. Fourth Edition. With 4 Coloured Plates and 66 Engravings. Fcap. 8vo, 10s. 6d.

NETTLESHIP.—The Student's Guide to Diseases of the Eye. By EDWARD NETTLESHIP, F.R.C.S., Ophthalmic Surgeon to, and Lecturer on Ophthalmic Surgery at, St. Thomas's Hospital. Second Edition. With 137 Engravings, and a Set of Coloured Papers illustrating Colour-blindness. Fcap. 8vo, 7s. 6d.

WOLFE.—On Diseases and Injuries of the Eye: a Course of Systematic and Clinical Lectures to Students and Medical Practitioners. By J. R. WOLFE, M.D., F.R.C.S.E., Senior Surgeon to the Glasgow Ophthalmic Institution, Lecturer on Ophthalmic Medicine and Surgery in Anderson's College. With 10 Coloured Plates, and 120 Wood Engravings, 8vo.

PATHOLOGY.

JONES AND SIEVEKING.—A Manual of Pathological Anatomy. By C. HANDFIELD JONES, M.B., F.R.S., and EDWARD H. SIEVEKING, M.D., F.R.C.P. Second Edition. Edited, with considerable enlargement, by J. F. PAYNE, M.B., Assistant-Physician and Lecturer on General Pathology at St. Thomas's Hospital. With 195 Engravings. Crown 8vo, 16s.

LANCEREAUX.—Atlas of Pathological Anatomy. By Dr. LANCEREAUX. Translated by W. S. GREENFIELD, M.D., Professor of Pathology in the University of Edinburgh. With 70 Coloured Plates. Imperial 8vo, £5 5s.

VIRCHOW. — Post-Mortem Examinations: a Description and Explanation of the Method of Performing them, with especial reference to Medico-Legal Practice. By Professor RUDOLPH VIRCHOW, Berlin Charité Hospital. Translated by Dr. T. B. SMITH. Second Edition, with 4 Plates. Fcap. 8vo, 3s. 6d.

WILKS AND MOXON.—Lectures on Pathological Anatomy. By SAMUEL WILKS, M.D., F.R.S., Physician to, and late Lecturer on Medicine at, Guy's Hospital; and WALTER MOXON, M.D., F.R.C.P., Physician to, and Lecturer on the Practice of Medicine at, Guy's Hospital. Second Edition. With 7 Steel Plates. 8vo, 18s.

PSYCHOLOGY.

BUCKNILL AND TUKE.—A Manual of Psychological Medicine: containing the Lunacy Laws, Nosology, Ætiology, Statistics, Description, Diagnosis, Pathology, and Treatment of Insanity, with an Appendix of Cases. By JOHN C. BUCKNILL, M.D., F.R.S., and D. HACK TUKE, M.D., F.R.C.P. Fourth Edition, with 12 Plates (30 Figures). 8vo, 25s.

PHYSIOLOGY.

CARPENTER.—Principles of Human Physiology. By WILLIAM B. CARPENTER, C.B., M.D., F.R.S. Ninth Edition. Edited by Henry Power, M.B., F.R.C.S. With 3 Steel Plates and 377 Wood Engravings. 8vo, 31s. 6d.

DALTON.—A Treatise on Human Physiology: designed for the use of Students and Practitioners of Medicine. By JOHN C. DALTON, M.D., Professor of Physiology and Hygiene in the College of Physicians and Surgeons, New York. Seventh Edition. With 252 Engravings. Royal 8vo, 20s.

FREY.—The Histology and Histo-Chemistry of Man. A Treatise on the Elements of Composition and Structure of the Human Body. By HEINRICH FREY, Professor of Medicine in Zurich. Translated by ARTHUR E. BARKER, Assistant-Surgeon to the University College Hospital. With 608 Engavings. 8vo, 21s.

SANDERSON.—Handbook for the Physiological Laboratory: containing an Exposition of the fundamental facts of the Science, with explicit Directions for their demonstration. By J. BURDON SANDERSON, M.D., F.R.S., Jodrell Professor of Physiology in University College; E. KLEIN, M.D., F.R.S., Assistant-Professor in the Brown Institution; MICHAEL FOSTER, M.D., F.R.S., Prælector of Physiology at Trinity College, Cambridge; and T. LAUDER BRUNTON, M.D., F.R.S., Lecturer on Materia Medica at St. Bartholomew's Hospital Medical College. 2 Vols., with 123 Plates. 8vo, 24s.

SURGERY.

BRYANT.—A Manual for the Practice of Surgery. By THOMAS BRYANT, F.R.C.S., Surgeon to, and Lecturer on Surgery at, Guy's Hospital. Third Edition. With 672 Engravings (nearly all original, many being coloured). 2 vols. Crown 8vo, 28s.

SURGERY—*continued.*

BELLAMY.—**The Student's Guide to Surgical** Anatomy; a Description of the more important Surgical Regions of the Human Body, and an Introduction to Operative Surgery. By Edward Bellamy, F.R.C.S., and Member of the Board of Examiners; Surgeon to, and Lecturer on Anatomy at, Charing Cross Hospital. Second Edition. With 76 Engravings. Fcap. 8vo, 7s.

CLARK AND WAGSTAFFE. — **Outlines of** Surgery and Surgical Pathology. By F. Le Gros Clark, F.R.C.S., F.R.S., Consulting Surgeon to St. Thomas's Hospital. Second Edition. Revised and expanded by the Author, assisted by W. W. Wagstaffe, F.R.C.S., Assistant-Surgeon to St. Thomas's Hospital. 8vo, 10s. 6d.

DRUITT. — **The Surgeon's Vade-Mecum; a** Manual of Modern Surgery. By Robert Druitt, F.R.C.S. Eleventh Edition. With 369 Engravings. Fcap. 8vo, 14s.

FERGUSSON.—**A System of Practical Surgery.** By Sir William Fergusson, Bart., F.R.C.S., F.R.S., late Surgeon and Professor of Clinical Surgery to King's College Hospital. With 463 Engravings. Fifth Edition. 8vo, 21s.

HEATH.—**A Manual of Minor Surgery and** Bandaging, for the use of House-Surgeons, Dressers, and Junior Practitioners. By Christopher Heath, F.R.C.S., Holme Professor of Clinical Surgery in University College and Surgeon to the Hospital. Sixth Edition. With 115 Engravings. Fcap. 8vo. 5s. 6d.

By the same Author.

A Course of Operative Surgery: with Twenty Plates drawn from Nature by M. Léveillé, and Coloured by hand under his direction. Large 8vo, 40s.

ALSO,

The Student's Guide to Surgical Diagnosis. Second Edition. Fcap. 8vo, 6s. 6d.

MAUNDER.—**Operative Surgery. By Charles** F. Maunder, F.R.C.S., late Surgeon to, and Lecturer on Surgery at, the London Hospital. Second Edition. With 164 Engravings. Post 8vo, 6s.

SURGERY—*continued.*

PIRRIE.—The Principles and Practice of Surgery. By William Pirrie, F.R.S.E., late Professor of Surgery in the University of Aberdeen. Third Edition. With 490 Engravings. 8vo, 28s.

SOUTHAM.—Regional Surgery: including Surgical Diagnosis. A Manual for the use of Students. Part I., the Head and Neck. By Frederick A. Southam, M.A., M.B. Oxon, F.R.C.S., Assistant-Surgeon to the Royal Infirmary, and Assistant-Lecturer on Surgery in the Owen's College School of Medicine, Manchester. Crown 8vo, 6s. 6d.

TERMINOLOGY.

DUNGLISON.—Medical Lexicon: a Dictionary of Medical Science, containing a concise Explanation of its various Subjects and Terms, with Accentuation, Etymology, Synonymes, &c. By Robley Dunglison, M.D. New Edition, thoroughly revised by Richard J. Dunglison, M.D. Royal 8vo, 28s.

MAYNE.—A Medical Vocabulary: being an Explanation of all Terms and Phrases used in the various Departments of Medical Science and Practice, giving their Derivation, Meaning, Application, and Pronunciation. By Robert G. Mayne, M.D., LL.D., and John Mayne, M.D., L.R.C.S.E. Fifth Edition. Fcap. 8vo, 10s. 6d.

WOMEN, DISEASES OF.

BARNES.—A Clinical History of the Medical and Surgical Diseases of Women. By Robert Barnes, M.D., F.R.C.P., Obstetric Physician to, and Lecturer on Diseases of Women, &c., at, St. George's Hospital. Second Edition. With 181 Engravings. 8vo, 28s.

COURTY.—Practical Treatise on Diseases of the Uterus, Ovaries, and Fallopian Tubes. By Professor Courty, Montpellier. Translated from the Third Edition by his Pupil, Agnes M'Laren, M.D., M.K.Q.C.P. With Preface by Dr. Matthews Duncan. With 424 Engravings. 8vo, 24s.

DUNCAN.—Clinical Lectures on the Diseases of Women. By J. Matthews Duncan, M.D., F.R.C.P., Obstetric Physician to St. Bartholomew's Hospital. Second Edition, with Appendices. 8vo, 14s.

WOMEN, DISEASES OF—*continued.*

EMMET.—**The Principles and Practice of** Gynæcology. By Thomas Addis Emmet, M.D., Surgeon to the Woman's Hospital of the State of New York. With 130 Engravings. Royal 8vo, 24s.

GALABIN.—**The Student's Guide to the Diseases of Women.** By Alfred L. Galabin, M.D., F.R.C.P., Obstetric Physician and Joint Lecturer on Obstetric Medicine at Guy's Hospital. Second Edition. With 70 Engravings. Fcap. 8vo, 7s. 6d.

REYNOLDS.—**Notes on Diseases of Women.** Specially designed for Students preparing for Examination. By J. J. Reynolds, M.R.C.S. Fcap. 8vo, 2s. 6d.

SMITH.—**Practical Gynæcology: a Handbook** of the Diseases of Women. By Heywood Smith, M.D., Physician to the Hospital for Women and to the British Lying-in Hospital. With Engravings. Second Edition. Crown 8vo. [*In preparation.*

WEST AND DUNCAN.—**Lectures on the Diseases of Women.** By Charles West, M.D., F.R.C.P. Fourth Edition. Revised and in part re-written by the Author, with numerous additions, by J. Matthews Duncan, M.D., F.R.C.P., Obstetric Physician to St. Bartholomew's Hospital. 8vo, 16s.

ZOOLOGY.

CHAUVEAU AND FLEMING.—**The Comparative Anatomy of the Domesticated Animals.** By A. Chauveau, Professor at the Lyons Veterinary School; and George Fleming, Veterinary Surgeon, Royal Engineers. With 450 Engravings. 8vo, 31s. 6d.

HUXLEY.—**Manual of the Anatomy of Invertebrated Animals.** By Thomas H. Huxley, LL.D., F.R.S. With 156 Engravings. Fcap. 8vo, 16s.

By the same Author.

Manual of the Anatomy of Vertebrated Animals. With 110 Engravings. Post 8vo, 12s.

WILSON.—**The Student's Guide to Zoology:** a Manual of the Principles of Zoological Science. By Andrew Wilson, Lecturer on Natural History, Edinburgh. With Engravings. Fcap. 8vo, 6s. 6d.